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REPORT ON CLASS 41.

PRODUCTS OF MINING AND METALLURGY.

BY

WILLIAM HENRY CHANDLER, PH. D., F. C. S.,
Expert Commissioner of the United States, and Member of the Jury of Class 41.

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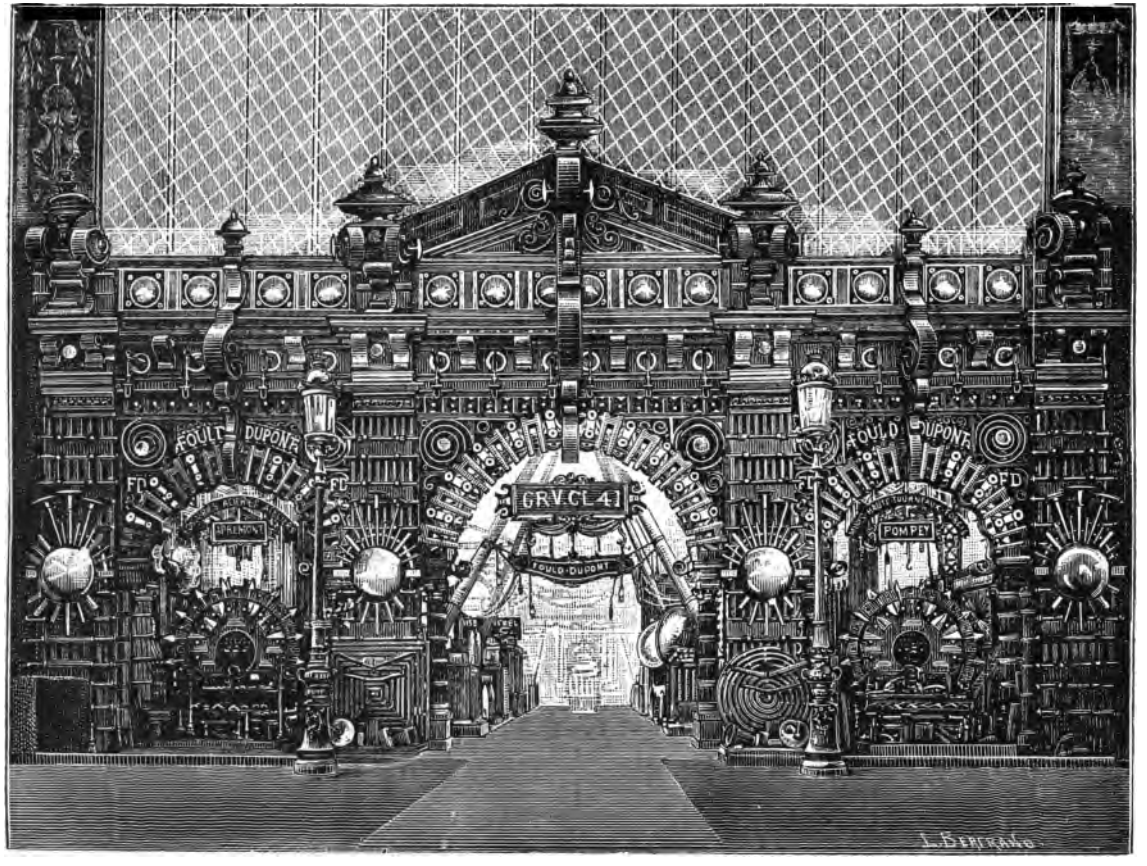


FACADE OF CLASS 41—EXHIBIT OF FOULD-DUPONT.

[See page 419.]

PRODUCTS OF MINING AND METALLURGY.

By W. H. CHANDLER, Ph. D.

CLASS 41.—PRODUCTS OF MINING AND METALLURGY.

There were 1,285 exhibitors in this class, and of these 53 received grand prizes and 191 received gold medals. Germany, one of the large iron-producing countries, was not represented.

The production of coal, iron, and zinc in 1876 and 1888 is given in the tables, as well as the production of some other metals. The great increase in the production by the United States has changed the relative positions of the metal-producing countries.

In the preparation of fuel there are various improved forms of coke ovens, utilizing the gases and condensing the useful by-products hitherto wasted. The collection of similar by-products in the blast furnace gases has also been accomplished. In iron metallurgy neutral and basic lining in the open-hearth furnace for the treatment of phosphoric pig is coming somewhat into use.

In metallurgic processes the most important is the basic Bessemer or Thomas-Gilchrist process, the first patent being dated 1878. In copper, the Manhes process by use of a converter dates from 1880; this idea was not new, as the writer remembers to have heard that the president of one of the copper smelting companies had filed a caveat for the use of the Bessemer process for refining copper mattes soon after the introduction of that process. In the metallurgy of zinc, the heating of the muffles for the production of spelter by gas and the regenerative system has come into use to some extent. With aluminium the greatest progress has been made by Americans, the Castner and Hall processes and the Cowles electric furnace being the inventions of our countrymen. The latter is the first successful application of electricity for furnace work. The application of electricity to the reduction of aluminium (Hall's patent) and to welding of metals (Thompson's patent) are also American inventions.

We note the large number of metallic alloys in use in the arts and the great progress in tempering and annealing. The studies of scientists on the structure and physical properties of metals have contributed not a little to the progress of metallurgy.

In this report, those processes and products are discussed which have made noteworthy progress since the Exposition of 1878.

Number of exhibitors and prizes awarded in Class 41.

Country.	Grand prizes.	Gold medals.	Exhibitors.	Country.	Grand prizes.	Gold medals.	Exhibitors.
Alsace Lorraine	1	...	1	Japan	...	...	6
Argentine Republic	1	1	15	Luxembourg	1	...	3
Austria-Hungary	...	1	5	Mexico	2	9	25
Belgium	5	20	97	Nicaragua	...	1	1
Bolivia	1	5	48	Norway	...	2	19
Brazil	2	4	35	Paraguay	...	...	1
Chili	1	2	6	Portugal	1	3	12
Colombia	...	1	1	Roumania	...	1	20
Domingo	...	1	12	Russia	1	12	50
Egypt	...	...	1	San Marin	...	...	4
Ecuador	...	...	5	Salvador	...	1	46
France	24	72	411	Servia	...	1	24
French colonies	1	6	136	Siam	...	1	1
Guatemala	...	1	30	South Africa Republic	1	1	6
Great Britain	3	20	59	Spain	1	2	27
G. B. Colonies	4	6	12	Sweden	...	...	1
Greece	...	3	20	Switzerland	6	2	16
Hawaii	...	...	1	United States	1	8	83
Holland	...	...	6	Uruguay	...	...	7
Honduras	...	1	1	Venezuela	1	1	19
Italy	1	2	13	Total	53	191	1,285

Production of coal, iron ore, pig iron, and steel, in tons.

Country.	Coal.		Iron ore.		Pig iron.		Steel.	
	1876.	1888.	1876.	1888.	1876.	1888.	1876.	1888.
Great Britain	135,477,282	169,935,219	17,111,049	14,590,713	6,642,895	7,998,969	545,560	3,734,130
Germany	*43,451,371	81,960,000	*2,072,250	10,664,800	*1,824,338	4,337,121	*126,500	1,862,000
United States	41,000,000	123,674,774	4,500,000	7,648,726	2,093,236	7,268,507	525,596	2,899,440
France	17,047,762	22,602,874	3,081,026	2,500,000	1,449,537	1,683,349	254,191	517,294
Belgium	14,329,578	19,218,484	269,206	†213,000	490,498	826,984	75,258	231,000
Austria	11,867,715	24,000,000	554,965	2,200,000	273,045	761,606	...	355,038
Russia	1,708,512	‡4,464,174	1,935,187	‡1,334,000	427,588	‡532,649	3,945	‡222,025
Spain	101,522	†1,000,000	436,586	4,500,000	56,462	200,000	2,720	114,537
Sweden	96,674	†300,000	787,092	939,540	348,257	457,052	18,785	‡24,500
Luxembourg	...	(§)	1,196,729	(§)	280,500	(§)	...	...
Italy	...	327,665	...	230,575	...	12,265	...	‡73,262

* Prussia only. † 1889. ‡ 1887. § With Germany.

Production of zinc, in tons.

Country.	1876.	1888.	Country.	1876.	1888.
Austria	3,979	3,827	Prussia	83,634	83,375
Belgium	49,960	133,245	Russia	3,990	3,785
France	17,434	16,140	Spain	2,940	(*)
Great Britain	6,747	26,638	United States	16,091	49,922

* With France.

Production of copper, in tons.

Country.	1879,	1888.	Country.	1879.	1888.
Africa	4,828	7,550	Japan	3,900	11,000
Australia	9,500	7,450	Mexico	400	2,766
Austria	1,269	1,868	Norway and Sweden	3,212	2,470
Canada	1,550	4,300	Russia	3,081	4,700
Chili	49,318	31,240	South America (except Chili)	4,497	5,850
England	3,462	1,500	Spain and Portugal	32,697	60,300
Germany	9,005	15,230	United States	23,000	103,128
Italy	1,140	2,500	Total	150,859	261,852

Production of lead in United States.

	Tons.
1876	64,070
1888	186,000
1889	190,000

The production of other metals in the United States was: Mercury, 1887, 33,825; 1888, 33,250 flasks of 76½ pounds each; antimony, 1887, 75 tons of 2,000 pounds; platinum, 1887, 448 Troy ounces; nickel, 1887, 205,556 pounds.

In 1886 Russia produced 138,792 Troy ounces of platinum.

Gold and silver production.

Year.	Gold.		Fine Silver (Troy ounces).	
	World.	United States.	World.	United States.
1877	$113,947,178	$46,897,390	69,913,712	30,777,870
1888	109,928,000	33,175,000	110,086,453	45,792,081
1889	118,882,000	32,800,000	126,000,000	50,008,875

Mineral products of the United States.

	1882.	1888.
Metallic products	$228,410,380	$256,245,403
Nonmetallic products	219,755,109	328,914,518
Unspecified mineral products	8,000,000	6,500,000
	456,165,489	591,659,921

COAL.

COKE OVENS FOR PRESERVATION OF AMMONIA AND TAR.

These ovens have come considerably into use in England, and especially in Germany. In France they are in use at a few collieries, but their use here does not seem to be extending. In Germany, however, the number is increasing. In the United States very little has been done in this direction.

There are many forms and modifications of ovens and their accessories. In England the Carves and Simon-Carves ovens are used, as well as in France. In Germany the Hoffman and the Hoffman-Otto are used, and the older forms of ovens have been adapted and altered in order to utilize the gases given off during coking, for the purpose of heating the ovens and for the recovery of the tar and ammonia.

JAMESON OVEN.

In these the gases are withdrawn in a beehive oven through a hollow floor.

Some experiments made with similar ovens at the Calumet Iron and Steel Works by the National Coke and Fuel Company, of Chicago, are said to have yielded 15,000 cubic feet of gas, 365 gallons of coal oil, and 3 pounds of sulphate of ammonia from a ton of coal.

The gases are withdrawn about 10 inches above the surface level of the charge of coal, opposite the charging door. The tar is said to contain phenols and paraffine, but is deficient in benzole.

CARVES COKE OVENS.

These are rectangular ovens built in block, with bottom and side flues. The gases are withdrawn at the top, and, after passing through the condensers, by means of an exhaust, forced into the lower flues, together with a current of cold air for its combustion.

SIMON-CARVES COKE OVEN.

In these the air is previously heated to 500° or 600° C., by passing through flues in contact with hot flues conveying away the spent fire-gases from the flues of the ovens. The amount of coke obtained is 75 tons against 63 by the beehive ovens. The quantity of tar is about 5 gallons per ton of coal. At the Terrenoire Works in France, the gases, after being deprived of the tar and ammonia, are passed through scrubbers, consisting of upright cylinders filled with pebbles, over which trickles the heavy oil obtained from the distillation of the tar. By this means a quantity of benzole is separated from the gases; from the scrubbers the gases pass through washing boxes bubbling

through heavy oil and dissolving still more benzole. Five and one-half pounds of benzole per ton of coal has been obtained.

	Analysis of tars from—	
	Carves ovens.*	Simon-Carves ovens.†
	Per cent.	*Per cent.*
Light oils	4.50	5.12
Creosote oils	20.40	7.44
Anthracene oils	34.20	34.08
Naphtha	.....	3.05
Pitch	.....	45.17

*Analysis by Watson and Sadler. †Analysis by Ernest Wirth.

Further treatment of distillate gave—

[Per cent. on tar.]

Water	10.00	.....
Fifty per cent. benzole	0.50	0.708
Solvent naphtha, 90 per cent	0.60	1.031
Heavy naphtha	0.40	*0.434
Crude carbolic acid	0.05	0.305
Creosote oil	46.50	†0.352
Anthracene	0.74	2.396
Pitch and loss	41.21	.....
	100.00	

* Burning naphtha, 30 per cent. †Cresote, crude.

One ton of tar yields 1.44 gallons 50 per cent. benzole and 48.2 pounds of 28 per cent. anthracene.

The cost of the Simon-Carves ovens in England has been given at £200, against £56 for a common beehive oven.

THE HOFFMAN COKE OVENS.

These ovens make use of the Siemens regenerators, the ovens being built in a block and the regenerators being long flues filled with fire bricks in the usual way, extending below the whole row of ovens on either end, thus constituting two continuous regenerators which communicate at one end with the chimney. Beneath each oven is a bottom flue which is divided by a cross partition into two equal lengths which communicate with the regenerator on its respective side. The bottom flue also is connected with perpendicular flues placed in the side walls of the oven above, which discharge into an upper flue, running the whole length of the wall. A large gas pipe

is placed outside the ovens, extending the whole length of the block on both sides, which discharges the gas into the bottom flues by means of branch pipes and valves.

The gas given off by the coking of the coal is withdrawn from the ovens through openings in the top of each oven, and passes into a a common main to the coolers and washers, for the removal of the ammonia and tar, a fan exhaust being placed beyond the washers. The same fan forces the gas to the gas mains at the ovens, and at the same time another fan forces air through the regenerators on one or the other side of the block of ovens. The gas and heated air meeting in the bottom flues combustion ensues there and in the side flues, the gases passing upward through half the flues of each oven and downward through the other half, thence through the other regenerator to the chimney. At the proper interval, about an hour, the valves are reversed and the current of gases pass in the opposite direction, the air being heated in the other regenerator. The wall partitions of the side flue are 3½ inches thick. The temperature of the air is 1,800° F., and there is generally a surplus of gas. A charge of 5 tons 13 cwt. of coal requires about 48 hours for coking. The coke is equal in quality to that obtained from ordinary ovens. The yield is several per cent. higher, owing to the air tightness of the openings for charging the coal and discharging the coke and to a slight pressure of gas in the ovens.

Temperatures.—Bottom flue, 2,200° to 2,550° F. Side flue, 2,000° to 2,200° F. Regenerators, when air first admitted 1,800°, an hour afterward 1,330°. In the chimney 800° to 932°.

The coolers, through which the gas from the ovens first passes, consist of vertical iron cylinders containing vertical iron tubes, water passing through the tubes and the gas in the opposite direction outside them. The gas in the rising tubes from the ovens 1,200° to 1,300°, in the common main 400° to 750°, before the coolers 170° to 250°, beyond the coolers 65° to 85°. The washers through which the gas next passes are vertical iron cylinders containing a great number of perforated plates placed horizontally over one another. Water trickles downward and washes the gas passing upward. Here will be deposited the tar and ammonia not condensed in the coolers. Temperature of the water 55° F. The cooling surface of the coolers is 5.72 square feet and of the washers 7.8 square feet per 1,000 feet of gas.

The yield of ammonia, estimated as sulphate of ammonia, is 1 per cent. of the weight of coal, and of tar 3 per cent., varying of course with the nature of the coal. The tar contains less benzole and an equal amount of naphthaline and anthracene as coal tar from gas works.

Analysis of the gas.

	Per cent.
Ethene	1.63
Methene	36.11
Hydrogen	53.32
Carbonic oxide	1.41
Carbonic acid	6.49
Sulphureted hydrogen	0.43
Benzole vapor	0.61
	100.00

Production of gas per coke oven, per day, 24,700 cubic feet; required for coking process, 17,700; surplus, 7,000 cubic feet, which can be used for heating the boilers.

Analysis of tar from Hoffman-Otto coke ovens, by G. Lunge.

	Per cent.
Aniline benzole	1.68
Crude naphthaline	7.69
Crude phenols	2.23
Anthracene, 33 per cent	1.50
Creosote oil	8.24
Anthracene oil	42.76
Pitch	30.55
Water	....
	98.38

Equal in volume to best description of tar from gas works.

RECOVERING OF TAR AND AMMONIA FROM BLAST FURNACE GASES.

The firm of William Baird & Co., of Scotland, have adopted the Alexander & McCosh process, the coal used being a splint coal and used raw. The gases of eight blast furnaces are collected and passed through an atmospheric condenser similar to those used in ordinary gas works, 200 iron tubes, 40 feet long, 2½ feet in diameter. The gases upon entering have a temperature of 300° to 400° F. and on leaving 120° F. They then pass through the water condenser, 45 by 18 by 45 feet, iron tubes surrounded by water, and are reduced in temperature to 60° to 70° F. In these two condensers there are 2¼ square feet of cooling surface to every 1,000 cubic feet of gas per 24 hours, 30 gallons of water to the ton of coal are condensed here from the gases, but the amount of tar is small. From here the gases pass to the scrubber, 80 by 25 by 25 feet, containing twenty-nine perforated diaphragms, set at an angle. The wash water trickles downward through the scrubber. The gases pass through a second scrubber, 60 by 20 by 20 feet. The liquor of the second scrubber is run back to the first scrubber, and worked up at 2.5°, Twaddell.

In the gases leaving the first scrubber is ammonia equal to 2 pounds sulphate per ton of coal and in the exit gases from the second scrub-

ber 2 to 3 ounces per ton or to 125,000 cubic feet of gas. There is in all 5 to 7½ pounds of ammonia in 125,000 cubic feet of gas.

There are three sets of Roots' blowers. The ammoniacal liquor is boiled off in six large boilers, 9 feet diameter and 30 feet long, heated by the waste gases. The liquor flows from one to the other, in the last one lime is introduced to set free the fixed ammonia. The ammonia given off is conducted into oil of vitriol held in saturators, round iron tanks lined with lead. The saturated liquor is evaporated in iron boxes lined with lead, and heated by lead steam pipes. The crystals of sulphate of ammonia are ladled out of these evaporators.

The tar is distilled in six stills, holding altogether 10,000 gallons. The yield is 50 to 60 parts water, 15 to 20 oil, and the rest pitch. The yield of sulphate of ammonia is 22 to 23 pounds per ton of coal and 40 gallons of crude tar or 16 gallons of boiled tar.

The Dempster & Henderson processes vary in construction of the apparatus from the foregoing, the cost of the former is £6,000 per furnace, and of the latter £5,000 per furnace.

In the Addie process at the Langloan Works, the gases are mixed with sulphurous acid gas to combine with the ammonia as sulphite; the sulphurous acid gas is produced by the combustion of waste materials containing sulphur. The mixed gas passes through two scrubbers, entering the first at 500° F. and leaving the second at 140° F. The sulphite of ammonia liquor is concentrated, decomposed with lime, and allowed to fall through a tower with diaphragms. An upward current of superheated steam at 800° F. expels the ammonia, which is conducted to saturators, lead-lined boxes 6 by 5½ by 3 feet. The saturated acid is settled and boiled down as usual.

The Neilson process, in use at the Summerlee Works, absorbs the ammonia in dilute sulphuric acid in the second scrubber, the gases entering the first scrubber at 500° F. and the second at 140° F. From four furnaces, consuming 300 tons of coal per 24 hours, the plant for this process would cost £8,500, and turn out 25 pounds of sulphate of ammonia per ton of coal. The make of tar is less than by the condensation processes, which produce 50 per cent. more.

The composition of these tars varies with the process; the hot or acid processes give tars of a higher specific gravity and containing only the higher burning oils. The specific gravity is as high as 1.09. They contain less oil and more pitch than the tar from the condensation and cooling processes. Twenty to 25 per cent. of oil is obtained from the boiled tar of the hot process and 30 to 42 per cent. from the cool process. Creosote oils from the hot process contained 20 to 25 per cent. of phenols and that from the cool process 20 to 40 per cent. The light oil contains paraffine, basic bodies, and phenols.

IRON.

PERCY C. GILCHRIST, LONDON, ENGLAND.

Raw and finished material to illustrate the basic or Thomas-Gilchrist process. This exhibitor received a grand prize.

These are exhibits of the Thomas & Gilchrist process for the dephosphorization of iron and the production of steel. This is called in some countries Thomas iron. G. J. Snelus proposed the name "basic process." It is also called "Basic Bessemer process."

Mr. Grunner first clearly discussed the condition necessary for the dephosphorization of pig-iron in 1867. In 1869 magnesian bricks were tried on a small scale by a Parisian engineer, and two patents for dephosphorization by basic linings in converters and open hearth were taken out. In 1872 G. J. Snelus, of England, took out a patent for lining of cupolas, furnaces, Bessemer converters, etc., composed of lime or limestone, wholly calcic or magnesian, and burned at the highest possible temperature. In 1878 S. G. Thomas, of England, obtained a patent for the addition of basic material, such as lime, lime and magnesia or lime and iron ore, to melted pig-iron contained in a Bessemer converter or open hearth furnace, with a calcareous or magnesian lining. The quantity of such addition is five times the phosphorus and silicon in the charge.

In 1879 the same person obtained a patent for blowing the melted metal in the converter, lined with basic material and containing basic material, for from 1 to 6 minutes after the disappearance of the carbon lines and until the chimney emits copious brown smoke and the flame is edged with white smoke. In the same year the same person obtained a patent for the use of a mixture of lime or magnesian lime and tar or tar and creosote, for the manufacture of refractory bricks and furnace linings. Thomas obtained a patent in 1879 for first refining the metal in a fixed Bessemer converter with a siliceous lining and then finishing the refining in a basic converter. The silicon would be taken out in the first and the phosphorus in the last.

In 1878 Edward Riley, of England, obtained a patent for the use of a mixture of lime and petroleum and similar oils. He mentions tar, but does not claim it.

These patents are the controlling patents of the basic Bessemer process of the present time.

Jacob Reese, of Pittsburgh, Pennsylvania, has obtained patents which are said to interfere with these in certain particulars. He also has some patents which supplement these in the process, under certain conditions. In 1883 he obtained a patent for the addition of phosphoric slag from the basic converter to the blast furnace, to

increase the phosphorus in basic Bessemer pig iron when the ores did not contain sufficient phosphorus. In the same year another patent for supplying the exact amount of air necessary to the after blow. In the same year another patent for utilizing forge cinder containing phosphorus. In the same year, for the combination of a basic converter and an acid open-hearth furnace for the making of high carbon steel for high phosphoric pig-iron, which is difficult to accomplish by the basic converter. In 1889, for the combination of the acid Bessemer converter and the basic open-hearth furnace. This process would be useful with ores rich in silicon and phosphorus.

The basic lining of the converters is composed of basic brick of newly burnt lime, or magnesian lime better, and coal tar, a limestone containing 6 per cent. silica, 2 per cent. alumina, 1.5 per cent. oxide of iron, and magnesia being to the lime in the proportion of 2 to 3. The calcination of the limestone should be conducted at a very high heat. The calcined limestone is mixed with the tar, warm, in a mortar mill, 6 to 17 per cent. of tar being used. To make bricks or Bessemer tuyères in molds with great pressure, 6 to 10 per cent. is sufficient. The bricks are burnt in kilns at a very high temperature. The bricks are set in the converter with a similar mixture of calcined limestone and tar as a cement. When the mixture, instead of the bricks, is used for ramming the linings, 10 per cent. of tar is sufficient.

The tuyères are made as above or the bottoms are rammed with the mixture around iron rods, the withdrawal of which leaves the openings for the blast. The repairs are performed by liquid lime-tar without cooling the converters. In regard to the durability of the linings it is stated that more or less extensive repairs are necessary after an average of fifty-six blows. The bottoms last an average of fourteen blows. The consumption of basic material is 48 kilos per 1,000 kilos of steel. In the acid process the consumption of gannister and tuyères is 40 kilos.

The converter is heated up with coke and lime mixed with small coal added. This is blown for a few minutes to heat up the lime. An average of 15 per cent. of lime on the steel produced is used. The metal is then run in and the blowing continued up to the vanishing point of the carbon lines of the spectrum and an after blow until a copious brown smoke is emitted from the converter and a white smoke around the edge of the flame. The duration of the whole blow is from 12 to 25 minutes. A test piece is taken shortly before the blow is finished; this is flattened hot under the hammer, chilled in water, and broken. If the metal is hard and has the characteristic appearance of phosphorus, the blow is continued for the period dictated by experience. A second test is rarely taken. The slag is run off and the spiegeleisen added. This running off of the slag prevents the reduction of the slag by the addition of the spie-

geleisen. Another method is to pour half the metal into the ladle, then add a quantity of Bessemer pig to reduce oxide of iron and get rid of gases, then the remainder of the metal is poured and the spiegeleisen added. The length of the first blow varies, as given by one authority, from 9 to 13 minutes and of the after blow 2 to 3½ minutes. The number of blows in 24 hours is generally considerably less than with the acid process, though some German work claims equal production. The loss of metal is given an average of 15 per cent. against 12 per cent. in the acid process.

The metal is applied to most of the purposes for which metal for the acid process is used. The slag contains from 17 to 20 per cent. phosphoric acid, and 50 per cent. lime and is used for agricultural purposes.

Order of elimination of impurities from iron.

Acid lined converter.	Basic lined converter.
1. Silicon.	1. Silicon.
2. Carbon.	2. Carbon.
3. Manganese.	3. Phosphorus.
4. Iron.	4. Manganese.
(not eliminated)	5. Sulphur.
Sulphur.	6. Iron.
Phosphorus.	

A diagram in a paper by J. Massenez, before the Iron and Steel Institute, illustrates the elimination of impurities in a basic blow:

Carbon quite steadily was consumed by the ninth minute. Silicon rapidly was consumed by the second minute. Phosphorus slightly consumed till the ninth minute, then rapidly by 11½ minutes. Manganese gradually consumed by 11½ minutes. Sulphur increases slightly to the ninth minute, by 11½ minutes disappears.

	Charge.	11½ Minutes.	Steel.
Silicon	0.83	Trace.	Trace.
Carbon	3.05	0.12	0.24
Phosphorus	1.37	0.04	0.08
Manganese	0.41	0.07	0.36
Sulphur	0.33	0.18	0.12

These analyses are given simply to illustrate the above-mentioned diagram and not as an average example of the process. Whereas in the acid Bessemer process the heat is furnished chiefly by the oxidation of the silicon, in the basic Bessemer process the heat is furnished largely by the combustion of the phosphorus, which enters into combination with the basic materials and passes off in the slag.

Prof. W. B. Philips states that since 1878, when this process was first started, including 1888, there has been produced more than 8,000,000 tons of basic Bessemer steel, of which scarcely 50,000 tons have been produced in the United States, while now it is not made at all there.

A suitable pig-iron for this process contains, carbon, 2.5 to 3.1; phosphorus, 2 to 3; sulphur, 0.6 upper limit; silicon, 1.5 upper limit; manganese, 1 to 3.

It is difficult to find suitable ore for this pig-iron; the most favorable outlook is in the Southern States. In 1888, of basic steel, Great Britain produced 408,594 tons. Of basic Bessemer pig-iron, Germany produced 1,253,308 metric tons. Deducting 15 per cent. for loss, this would leave 1,065,312 tons of steel. France is estimated to have produced 143,000 tons in 1887.

In 1889, in France, the aggregate annual capacity of basic converters was 500,000 tons.

Bessemer steel produced in the world.

Year.	Acid.	Basic.	Total.	Per cent. basic.
1881	4,333,470	200,000	4,533,470	4.44
1888	4,942,471	1,984,484	6,926,955	29.10

In the foregoing it is intended to give a general statement of this most important iron process, developed since 1878, without discussing the varieties of iron used or the steel produced.

SCHNEIDER ET CIE., CREUSOT, FRANCE.

This firm exhibited only basic slag and plants fertilized by use of it. They offer this material as a fertilizer, finely ground and sifted, at 30 francs per ton in bags, at their works; it contains from 12 to 18 per cent. of phosphoric acid. It has been shown that most of the acid is in combination with lime and as tetra-basic phosphate. The slag may be ground to the fineness of a 100-mesh sieve and applied without acid treatment. The phosphoric acid is regarded as half as valuable as a fertilizer as that contained in soluble phosphates. As the quantity of basic slag is nearly one-third as much in weight as the iron produced by the basic process, this material becomes a factor in the cost of the metal if a market can be made for it. In Germany 300,000 tons per annum are used, one-third of which comes from England and Austria.

CLAPP-GRIFFITH'S PROCESS.

This process employs a stationary converter, 1 to 3 tons capacity, with side blast and a slag spout at such a height that the slag runs out during the boil. There is a tap-hole through which the steel is removed at end of the blow. The bottoms are said to last much longer than those of the Bessemer converter, the linings about the same.

In the report of the American Iron and Steel Association for 1889, it is stated that the Clapp-Griffith's process does not grow in favor in America, no new plants having been erected in 1889, while the process was practically abandoned during the year at two works. Five Clapp-Griffith's plants with nine converters were employed in 1889 in the production of Bessemer steel out of six plants with eleven converters existing. Eighty-two thousand eight hundred and fifty net tons of steel were made here by this process in 1889. No noteworthy amount of Clapp-Griffiths steel was made in Great Britain in 1889. At several works the process has been discontinued. The product in 1888 was 20,000 tons; in 1887 25,000 tons. In France the process has been abandoned.

SOCIÉTÉ ANONYME DES HAUTS FOURNEAUX FONDERIE, FORGES ET LAMINOIRS DE STENAY (MEUSE), FRANCE.

Received a silver medal.

This exhibit consists of a great variety of weldable steel castings, produced by the Robert process, which employs a movable converter from 1 to 3 tons' capacity, a cross section of which has the shape of the letter D, and swings upon trunnions supported by suitable bearings. The tuyères are five or six in number, situated upon the straight side of the converter, in the same plane, horizontally, but at unequal angles with the straight side. The lining is either basic or acid, as may be desired. The acid lining may be made of highly siliceous bricks. The following composition gives good results:

	Per cent.
Silica	96.75
Alumina and oxide of iron	2.55
Lime	0.40
Various	0.30
	100.00

The mortar used must be very refractory.

If clay, sufficiently refractory, and capable of binding well when rammed, can be obtained, it is preferable to making the lining of composition. Its cost is less and construction is more rapid. The tuyères are either of burnt clay or made in the lining. The bottom lasts much longer than in Bessemer.

The basic lining consists of calcined dolomite, as free from silica as possible, powdered and mixed with 20 per cent. of coal tar, free from water. Bricks may be made of this mixture under heavy pressure, and joined by same mixture. The tuyères are situated near the melted surface of the iron bath, so that the blast does not penetrate through the whole bath, but only acts on the superficial layer, communicating a gyratory motion, bringing every part of the bath successively in contact with the blast.

The converter is also at certain stages tilted to aid the conversion. The metal is 10 to 15 centimetres in depth above the tuyères. The average pressure is 4 pounds. The blow lasts from 11½ to 14 minutes. At the end of the blow 1 per cent. of 70 per cent. ferromanganese is added.

At the Paris works the pig-iron used for acid steel contained:

	Per cent.
Carbon	3.50
Silicon	2.00
Manganese	1.00
Sulphur	0.05
Phosphorus	0.05

Average analyses of twenty-four samples acid steel at Stenay:

Carbon	per cent..	0.25
Silicon	do	0.144
Manganese	do	1.077
Tensile strength per square inch	tons...	31.3
Elongation	per cent..	16.3

Pig-iron, which gave best results with basic process, contained:

	Per cent.
Sulphur	.04
Manganese	1.80
Phosphorus	2.0 to 2.5
Silicon	0.50

The slag contains from 15 to 25 per cent. of phosphoric acid.

Basic steel made at Blaenavon Works.

	1.	2.	3.	4.
Carbon	.112	.122	.102	.084
Silicon	.027	.022	.035	.100
Sulphur	.136	.048	.032	Trace.
Phosphorus	.080	.052	.049	.076
Manganese	.258	.411	.307	Trace.

It is claimed that with a much smaller or much cheaper plant than the Bessemer plant the composition of the resulting steel can be regulated, and that by the acid process steel of any desired quality

can be produced, especially for castings of high quality of soundness and finish; that by the basic process a peculiarly soft ductile metal is produced.

The process is in use at Stenay, and in Paris, and at the Blaenavon Works in England. The foregoing statements are mainly from a paper read before the Iron and Steel Institute of Great Britain by F. L. Garrison.

In the report of the American Iron and Steel Association for 1889 it is stated that this process was introduced in the United States in 1888 at Springfield, Ohio.

During 1889 six other plants were completed and one commenced. Six of these plants with ten converters made steel, mainly for experimental purposes, and the quantity produced was very small. The plants are all small and most of them are designed for making castings.

MANUFACTURE OF BASIC OPEN-HEARTH STEEL AT THE BRYMBO STEEL WORKS, BRYMBO, WALES.

The following extracts from a paper by J. H. Darby, of Brymbo, read before the Iron and Steel Institute of Great Britain, best describes this process:

The next work was that of designing and building four 12-ton and afterward two 20-ton furnaces. They were arranged in a line, the charging platform on one side being a sufficient distance above the floor of the works to admit the casting ladle and carriage, which runs on rails over a pit parallel to the furnaces.

Each furnace is provided with a separate chimney, ordinary butterfly reversing valves of ample size, and regenerator chambers of large capacity, but similar in shape and construction to most modern open-hearth furnaces.

The furnace proper is composed of two wrought iron sides supported by H-iron buck-staves, well braced together at the top and bottom. The ends are left open, holes are cut in the plates for the three doors on the front side of the furnace and another hole is made at the back for tap-hole plates. The plates are also cut away to allow air to circulate for cooling purposes under the furnace bottom and bridge plates. The bottom of the furnace is built up of cast-iron plates, supported on H-iron girders, so as to form a rough outline of the furnace bottom when lined and ready for work. The girders rest on angle iron attached to the side plates. Any movement or subsidence in the chambers must therefore affect the hearth as a whole. This prevents cracking of the material of which the hearth is composed. The silica blocks at each end of the furnace are built in the usual manner, but the roof and side walls are built after the hearth has been rammed in. The former is placed some way above the metal, so as to avoid splashing of the basic slag. The

roof is level from block to block; the ends, however, are well inclined to bring the flame down on the metal.

On the iron plates for holding the dolomite hearth fire bricks are placed so that no part of the basic hearth when finished is more than 15 inches thick. As soon as all the brickwork is dry, hard burnt dolomite, well ground and mixed with as little anhydrous tar as will make it stick together when compressed, is rammed with hot irons until the desired shape of the hearth is built up. The tap-hole is made by a round piece of wood, which is left in and burnt out as the furnace heats up.

The shrunk dolomite or basic material is brought up to the bottom of the doors, and to an equal height all round. On it a layer of about 2 inches of chrome ore, also ground fine and mixed with tar, is rammed to act as a neutral separator between the acid and the basic portions. Chrome ore is also rammed in between the silica blocks and the basic hearth. The side walls and jambs are built in the chrome ore. The roof is then put on and the furnace heated up at first with a coal fire. There should be no stoppage in putting in a hearth and finishing the roof. A 20-ton furnace should thus be completed in 36 to 40 hours. When the furnace is properly dried and heated the hearth will become very hard. The tap-hole should be cleaned out, and then filled with dry ground basic material for several inches. This should be well pushed up against a scraper held from the middle door. Anthracite coal is then rammed in and the outside of the tap-hole is covered with damp sand.

The charge may now be introduced.

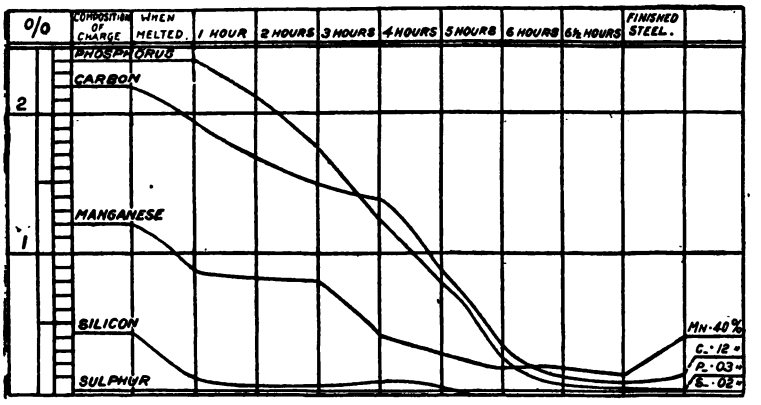
The pig-iron contains carbon (combined) 3.20, phosphorus 3.00, sulphur 0.04, silicon 0.40, manganese 1.75. I use 80 per.cent. pig and 20 per cent. scrap. The pig I have described. The scrap is composed of either steel or wrought iron. The percentage of phosphorus in wrought iron is not injurious. Limestone is usually charged in sufficient quantity to make a basic slag from the first. Scrap and pig follow. When melted and sufficiently hot, additions of iron ore and limestone are made at intervals during about five hours. The first sample is taken, and from its appearance and fracture it is judged if sufficient ore has been added. If so, as much as possible of the unspent oxide is reduced in the slag by reacting on the remaining impurities, lime additions being made from time to time. The hammered sample rapidly improves. The edges, which were rough at first, become smooth and free from cracks, the surface of the sample is clean, and when the charge is ready it will bend over into four thicknesses without any indication of cracking. Ferromanganese is then added, part in the furnace and part in the ladle, and the charge is trammed. It runs quietly and solidly, as shown by the fact that the total loss in the mill, including furnacing,

crops, and cobbles, is only 8 per cent. in the weight of the ingots produced—that is, in rolling billets, bars, and slabs.

Any kind of iron ore may be used in the steel furnaces, providing it contains a low percentage of silica. Phosphoric acid in the ore does not matter; the phosphorus is already oxidized and is taken up by the lime. Phosphorus can be as easily eliminated from pig-iron with pottery-mine as with hematite ore.

The diagram which I have had prepared was worked with 3.1 cwts. of pottery-mine, and that was equal to 4.2 cwts. of good rough carboniferous limestone per ton of ingots.

BASIC OPEN-HEARTH CHARGE.



The 20-ton furnaces make from 180 to 200 tons of ingots per week, or 25 cwts. per hour, exclusive of Sundays.

The yield of ingots from the weight of pig, scrap iron, and ferromanganese used, inclusive of iron reduced from the ore, is 93.5 per cent. The consumption of fuel, inclusive of Sundays and heating up furnaces that have been off, is 11.07 cwts. per ton of ingots.

Repairs to the hearth are made with ground dry basic material alone after each charge, if the furnace requires it, as is generally the case to some extent round the slag line. The repairs are quickly effected, and the furnace is at once ready to charge.

In the basic Bessemer process I understand that as much as 30 pounds of 80 per cent. ferromanganese is used per ton of steel. In the basic open hearth 10 to 12 pounds per ton is all that is required to give an equal percentage of manganese in the final steel. This seems to me to indicate a striking difference in the composition of the purified material from the two processes. After experience in the manufacture of over 60,000 tons of basic open-hearth steel, I can say I have never seen "red short" material in our usual soft quality, although I have kept a strict lookout for it. If care is taken to keep the sulphur low, say to 0.02 per cent., which is about our average, and if at the same time the excess of oxide is well worked out of the steel

prior to tapping, the metal will work and weld freely with a very small addition of manganese.

I have obtained 3,660 tons of dead soft steel from one furnace without relining, and it is still at work. The hearth has never been out of order since the furnace was started last December.

Molten pig-iron direct from the blast furnace was at one time poured onto the heated scrap in the open-hearth furnace; but although the hearth was well protected with limestone spread over the bottom, it was most rapidly destroyed, notwithstanding it had been in good condition previously. This method of charging was therefore abandoned. I may, however, say that the duration of the charge was shortened, and if the bottoms could be made to stand, it would be a considerable advantage.

I retain all the slag until the end of the charge, and as this is 25 to 30 per cent. of the weight of the metal produced, it will be readily understood that a furnace for the basic open-hearth process must be considerably larger than a furnace with an equal tonnage capacity working the acid process. Running slag off during the working of a charge means the wasting of oxide of iron. Slag from the basic open hearth usually contains 13 to 14 per cent. of phosphoric acid and has fewer shots of steel than basic Bessemer slag.

An average analysis of our soft steel is as follows:

	Per cent.
Carbon	0.12
Phosphorus	0.03
Sulphur	0.018
Silicon	Nil.
Manganese	0.40

This steel gives about 24.5 tons tensile strain per square inch and 15 tons elastic limit, with an elongation of 31 to 33 per cent. in 8 inches.

I would say in conclusion that I attach great importance, if uniform results are required, to the composition of the pig-iron. A suitable pig is as necessary in the basic as in the acid process of steel making, but it offers no more difficulty in manufacture.

FOULD-DUPONT, AT POMPEY (MEURTHE-ET-MOSELY), FRANCE.

The house originated in 1836; present works commenced in 1872; number of workmen 1,400 to 1,500.

The works include two blast furnaces, producing each 110 to 115 tons per day; twenty-five puddling furnaces, producing 150 tons per day; one Seimens-Martin furnace, magnesia brick lining, 36 to 42 tons per day, three heats; rolling mills producing 130 tons per day; six hammers, 1 to 3.5 tons, producing 150 to 200 tons of forgings per month; foundry producing 120 to 150 tons of castings per month. The shops turn out 100 to 200 tons finished work per month.

The works produce merchant iron and steel, plates, castings, and architectural work.

Exhibits.—Port d'Entrée of Class 41, in the Grand Gallery of 30 metres. This is composed of bars and plates of iron and steel, as types of rolling, ornamented by forgings, as types of finished pieces; volutes, and festoons of steel plates curved cold, as types of the quality of metal; and bucklers and casques examples of hammering and polishing. The pillars are composed of iron beams and shapes and large steel plates, and the columns of small profiles assembled in a circle. The arches carry guard-plates of the state railroads; the cornices, the couplers of the Southern Railroad, alternating with buffers of the Northern Railroad; the pillars, a variety of axles and buffers. The whole construction weighs 73 tons. It is a most ingenious as well as a beautiful exhibit, and extremely effective.

There are also large plates of steel, samples of ores, ingots, etc. All the iron for the Eiffel tower, amounting to 7,000 tons, was furnished by these works. They received a grand prize.

JACOB HOLTZER & CO., UNIEUX (LOIRE), FRANCE.

Founded in 1829; employs 800 to 1,000 men; consumes 30,000 tons of fuel.

Annual production.—4,000 tons crucible steel, of various qualities; 600 tons rolled steel; 3,000 tons puddled steel; 1,000 tons puddled iron; 2,500 tons cement, steel, and iron; 500 tons, parts of machines, etc.; 300 tons, bodies, tubes, and hoops of cannon, which do not require ingots of more than 3 tons; projectiles of forged and cast steel, up to 1 ton each; 200 tons sheets and plates of chrome steel, for protection.

The works include seven crucible furnaces, heated by gas, each holding thirty crucibles; each crucible holds 25 to 30 kilogrammes; metal and ingots as large as 3 tons are cast. The full daily product is 35 tons; twelve cementation furnaces, six of 30 tons' and six of 15 tons' capacity; eight to nine operations a year are made with each furnace; twenty-four hammers, 2 to 15 tons, rolling mills, machine shops, etc.

EXHIBITS.—*Ferro-chrome manganese.*—Chromium, 7; carbon, 4.35; manganese, 0.30.

Tungsten steel.—Up to 10 per cent tungsten, so-called mushet steel, for tools, without tempering; difficult to forge. Also a variety of steels, including carbon steel, chrome steel, chrome tungsten steel, manganese steel, silico-manganese steel, and copper steel; the latter up to 4 per cent. copper, but merely a study.

All these alloys are made in crucibles, the masses being 7 inches diameter 10 inches high.

The exhibit includes steel castings, steel bars of various kinds,

tools, parts of cannon, chrome steel projectiles first made by them in 1882, chrome steel plates up to 2 inches thick, for protection from shot.

This firm was out of competition, one of its members being on the jury.

For superior quality of tool steel Swedish iron is used, about 600 tons per year being consumed. Tungsten steel for tools is also made.

This firm exhibited a large number of alloys.

Chromium carburets.

Chromium....	80	71.5	60 per cent.
Carbon.....	11	3.46	8.6 per cent.

Type of ordinary manufacture:

Chromium....	48 to 53 per cent.
Carbon.....	8 per cent.

Silico chrome

Chromium....	82	30	30	42
Carbon.....	7.5	5	5	7.3
Silicon.....	8.2	8	8	2.1

Ferro chrome.

Chromium....	30	30	25	16	15	16	12.5	12	7	7
Carbon.....	sat.	4.7	3.8	9	2.25	2.7	sat.	2	sat.	1.2

Chromium 12, carbon 2, is not commercial, limit for cast iron and steel.

Limit for projectiles or tool steel is, chromium 1 to 3 per cent., carbon 1.5 per cent.

COMPAGNIE DES FONDERIES, FORGES ET ACIERIES DE ST. ETIENNE (LOIRE), FRANCE.

Founded 1865. Capital, 4,000,000 francs.

This company produces in acid and basic Siemens-Martin furnaces steel of various grades, with silicon, carbon, and chromium. They have no crucible plant and, with one exception, are the only manufacturers of projectiles of chrome steel in basic open-hearth furnaces. They endeavor to replace crucible steel in many of its applications, tools, cutting instruments, etc.

Composition of steel, parts in 10,000.

Quality.	Carbon.	Manganese.	Silicon.	Sulphur.	Phosphorus.	Chromium.
Z t	100	20	30	1	1	150
X 1	95	30	40	1	1	0
X 2	85	30	40	1	1	0
X 3	75	50	40	1	1	0
X 4	68	55	40	1	1	0
X 5	60	55	30	1	1	0

In regard to projectiles, they exhibited one of chrome steel 34 centimetres in diameter, which, having penetrated an iron plate of 40 centimetres, exhibits no appreciable deformation. It has been claimed that only projectiles of small caliber could be successfully made from open-hearth chrome steel.

The forging plant includes thirteen hammers, from 2 to 50 tons. Forging over a mandrel is practiced with hollow pieces. The rolling mills produce 10,000 tons of steel and 16,000 tons of iron and steel plates per annum.

The tempering is done by oil or water. The hoops for cannon are tempered in a special bath of a current of cold water. The company have taken the initiative in a process called central tempering with water, which seems superior to the total immersion in oil or water, for cannon tubes, or sleeves of great length. A current of cold water ascends within the piece, which has been properly heated, until cooling is complete. The cooling takes place first with the interior molecules, gradually proceeding outward, and it is claimed a greater uniformity is obtained.

The method of procedure for making chrome steel in basic open-hearth furnaces, as practiced by another maker, is given by Henry M. Howe. The carbon being brought to the desired point, ferro-chrome is added, allowing 20 per cent. loss of chrome. The chromium prevents blow-holes and gives forgeableness. When melted, the charge is tapped.

The exhibit consisted of tires, a crank shaft, trunnion hoops for a cannon of 42 centimetres caliber, plates of iron, steel, and chrome steel, a special steel to replace chrome steel plates of protection, axles, tube forged hollow over a mandrel, steel plate 20 centimetres thick, rudder of cast steel for cruiser *Alger*, and other steel castings, cannon, and projectiles, and a wheel entirely of forged steel. This company received a grand prize.

SOCIÉTÉ ANONYME DES ACIERIES ET FORGES DE FIRMINY (LOIRE), FRANCE.

Founded in 1854; made a stock company in 1867; area of property, 76 acres; capital, 3,000,000 francs. Sum total of business in 1888, 6,331,800 francs; in 1883, 12,245,425 francs. Employ 2,000 workmen, 58 steam engines, of total 3,000 horse-power.

This establishment includes one blast furnace, daily product, 100 tons; eight Siemens-Martin furnaces (here this process was first used commercially); twenty puddling furnaces; two cementation furnaces; three Siemens' gas furnaces, for crucible steel, forty crucibles each, with the necessary forging and rolling machinery; machine shops, etc.; twelve hammers, 1 to 30 tons.

The ore is obtained from mines of Mokta-el-Hadid (Algeria) and La Fragua (Spain), which latter is the property of the company. The

metal contains not more than 0.004 per cent. of phosphorus and trace of sulphur.

For producing high grade iron from ordinary pig, the Rollet refining process is used. The pig is melted in a basic-lined or water-jacketed hot-blast cupola furnace with fluor-spar and lime, by which most of the sulphur and some of the phosphorus is eliminated.

A great variety of steel is produced at these works, from ordinary to fine quality, cement steel, chrome steel, spiegel and silico-spiegel. The latter contains not higher than 20 per cent. silicon. The exhibit consisted of various samples of these products, with analyses and tests, with steel castings and forgings, and rollings for various purposes. Shafting, axles, springs, tires, wheels, cannon, anvils, industrial tools, agricultural tools, projectiles of cast and forged steel and of chrome steel, wire, galvanized and copper coated, and for pianos of cast steel. Their piano wire showed the highest tensile strength. This company received a grand prize.

MARREL FRÉRES, FORGES DE LA LOIRE ET DU MIDI RIVE-DE-GIER (LOIRE), FRANCE.

The members of this firm inherited their metallurgical tendency from their grandfather, François Marrel, who had a small factory at St. Martin-la-Plaine (Loire). On his death in 1823 the son Charles closed the factory and sought employment with another manufacturer. In 1845, with four of his sons, he reopened the factory. In 1853 the six sons formed the present firm and founded the present works. From that date to the present time the progress has been continuous. The firm has three establishments. That at Rive-de-Gier occupies 5 acres, and here is produced pieces of large dimensions for the national and merchant marine up to 35 tons; cannons of medium caliber up to 8 metres in length; projectiles of all kinds to 32 centimetres caliber. The works at Etaing were founded in 1867 and are the most important. They occupy 30 acres. Here are four Siemens-Martin furnaces of 35 tons each, twelve puddling-furnaces, two batteries of forty crucibles each, a 50-ton hammer, one hydraulic press of 4,500 tons and one of 2,000 tons, a rolling train for armor-plates with rolls 3½ feet diameter, 11 feet length, and 3¾ feet opening, and the necessary machine-shops, etc. A hammer of 100 tons, 6 metres maximum fall, under construction. Here are made armor-plate, cannon and projectiles of large caliber, and other large forgings. The works at La Capeletto were founded in 1855 and occupy 6 acres. Here are made forgings up to 10 tons; ships' anchors and chains, by a patented process, of all sizes; also, the assembling, by welding of elements, of large pieces. From 1860 to May, 1889, this firm has furnished to France and other Governments 43,520 tons of plates, simple and compound. From 1870 to May,

1889, they have produced 3,525 pieces of ordnance, from mountain howitzers of 3 inches to cannon of 13½ inches caliber.

The exhibits consist of iron crank-shaft for steamship, 19.8 tons; iron intermediate shaft for steamship, 13.2 tons; iron crank-shaft for steamship, 9.8 tons, finished; iron crank-shaft for steamship, 17.65 tons; anchor, 3.5 tons; anchor, articulated, 3.5 tons; chains, 56 to 70 millimetres; beams and angle of steel; plate for deck of ship, 17.200 by 2.920 by 0.060 metres thick, weight 26.3 tons; armor-plate, compound, 3.670 by 1.880 by 0.350 metres thick, weight 18.65 tons, one-third steel; series of tubes and bodies of cannon and mortars for land artillery, 80 to 240 millimetres diameter; series of tubes and bodies of cannon for marine artillery, 14 to 32 centimetres; hoops and trunnion-hoops of various dimensions, projectiles of chrome steel of various calibers, also model (one-tenth) of the 100-ton hammer.

This firm was awarded a grand prize.

COMPAGNIE DES HAUTS-FOURNEAUX, FORGES, ET ACIERIES DE LA MARINE ET DES CHEMINS DE FER, SAINT-CHAMOND (LOIRE), FRANCE.

Had its origin in 1842. Capital 20,000,000 francs; 6,000 workmen.

The company owns five works in France: St. Chamond, Assaily, Rive-de-Gier, Givors, and Adour; in Corsica, a blast furnace at Toga; also coal mines in the basin of the Loire, iron mines of St. Leon, Sardinia, and forests in Laidinia, for the supply of fuel to the furnace at Toga.

At St. Chamond there are open hearths of daily output of 60 tons, puddling furnaces of daily output of 8½ tons, hammers 5 to 15 tons, trains for rolling tires, rails, and shapes, plate mills for plates up to 2.20 metres wide; installation necessary for producing compound armor plates; a press of 4,000 tons, tools for finishing 4,000 tons of plates per year; hammers of 100, 35, 10, and 2 tons' weight, machine shops, and tempering plant.

At Assailly are five cementation furnaces, of 20 to 24 tons, four crucible furnaces, heated by gas, of 24 crucibles each, of daily capacity of 12 tons of ingots, and six puddling furnaces. Here is produced steel for tools and cutlery; here was established, in 1860, the manufacture of guns from cast steel, the monthly production reaching since that time 40,000 stands of arms.

At Rive-de-Gier, two shops, one for manufacture of pieces for naval construction, shafts, sternposts, etc., and axles of iron and steel for railroads. Annual production, 7,000 tons; eighteen hammers, 3 to 30 tons.

The other shop is for fabrication of wheels for locomotives and wagons; also for forging of wheels and projectiles. Six hammers, 2 to 40 tons. Annual product, 25,000 wheels, 5,000 to 7,000 tons.

At Givors are three blast furnaces, 50 to 60 tons' daily product, two

Bessemer converters, and two batteries of coke ovens. Annual product, 40,000 tons pig-iron, 20,000 tons steel.

At Boucan are the forges of Adour, built in 1882 to 1884. There are here three blast furnaces of 60 tons' daily output, with coke ovens; two Bessemer converters; two open-hearth furnaces of 10 tons, rolling mills for rails, shapes, etc., capacity 70,000 tons of rails per annum; rolls for merchant iron and a shop for producing tires, with hammers 6 to 12 tons. The total product has reached for a month 8,000 tons of pig-iron and 6,000 tons of rails or other products.

The exhibits include model of ingots of 100 tons, such as are now being forged for tube for cannon, 34 centimetres caliber and 42 calibers long; plate for cupola of a turret, 27 tons weight; plates of various dimensions, steamship shaft 14.5 tons; cannon tubes up to 34 centimetres, 14 tons; axles for artillery, hoops for cannon; railroad axles and tires; projectiles up to 42 centimetres and shells; turrets for land defense; repeating rifle; rapid firing cannon and various kinds of cannon; steel and iron rails and shapes, wheels, axles, tires, and steel railroad ties, system David; also large collection of samples and fractures of steel and iron with analyses. The ferrochrome contains 38 to 45 per cent. chromium.

Ferrotitanium, up to 22 per cent. titanium. Titanium steel contains 0.45 per cent. titanium.

This company was out of competition.

COMPAGNIE ANONYME DES FORGES DE CHATTILLON ET COMMENTRY.

Capital 12,500,000 francs. Founded 1845. Stock company 1862.

This company has the following works: At Montlucon St. Jacques (Allier), blast furnaces, forges, steel plant and shops of construction; at Commentry (Allier), blast furnaces and forges; at Beaucaire (Gard), blast furnaces; at Villerupt (Menthe-et-Moselle), blast furnaces; at Sainte Colombe, Ampilly, Mussy, and Chamesson (Cote-d'Or), and at Plaines (Aube), forges and wire mills; at Troncais (Allier), wire and cable mills; at Morat (Allier), special wire mills; at Vierzen (Cher), wire mills; at Cher, Indre, Villerupt (Menthe-et-Moselle), Butte (Alsace-Lorraine), ore mines; at Bezenet, Doyet, Les Ferrieres (Allier), St. Eloi (Pay-de-Dome), coal mines.

The annual product of the coal mines is 400,000 tons.

PRODUCTS.

Material of war for land and sea.—From 1867 to 1888 this company has furnished to the French Government 14,000 tons of iron plates and 7,000 tons of compound plates for ships; of twenty-five turrets this company has supplied twenty-one; in 1887 they constructed two land turrets for experiments at the camp of Chalons, one of one cannon, the other of two cannons, with eclipse, in con-

nection with the Compagnie de Fives, Lille, also a casemate of Hotchkiss type. They have also constructed for Belgium thirty-two of the sixty-three large cupolas of one and two cannons. Since 1875 they have furnished 70,000 projectiles of all sorts, besides 200,000 Hotchkiss projectiles from 1880 to 1885. Tubes and hoops for cannon of puddled or cast steel are made at Montlucon, St. Jacques. From 1887 to 1889 they have made twenty-one wire torpedo guards for the government at Troncais. Plates for marine construction and boilers are made at Commentry.

Manganese steel.—This company has made experiments with this metal, under the patents of R. A. Hadfield. (Journal of the Iron and Steel Institute, 1888, II.) With a composition of manganese 13.75, carbon 0.85, silicon 0.23, this metal has a tensile strength of 145,600 pounds per square inch and an elongation of 51 per cent. in 8 inches. It is very hard and practically non-magnetic. It is made by adding ferromanganese in a melted state to decarbonized iron.

Products of high grade for commerce.—Crucible steel for tools; steel castings; products for railroads, wheels, and tires; cables of any resistance and composition; wire of iron or steel of resistance from 60 to 220 kilogrammes per millimetre; piano wires.

Ordinary products for commerce.—Iron and steel in all forms, rolled, forged and cast; pig-iron, spielgel, and ferrochrome; charcoal and coke.

The exhibit included a large number of steel castings for ships, wheels, axles, tires for railroads, plates for protection, tubes for cannon, projectiles, armor-plate, iron and compound, wire of all kinds and cables, torpedo guard-nets, fracture samples of various steels and irons; carbon, tungsten, and chrome steels. Machine for measuring the dilatation of metals at elevated temperatures, designed by A. Evrard. Lunette pyrometrique of Messrs. Mesure and Nouel, for determining the temperature of incandescent bodies. This instrument was made by E. Ducretet, 75 rue Claude Bernard, Paris.

Lead tempering.—This company employ the method devised by its former director-general, Alfred Evrard, whom we quote:

> The process of immersion which we have adopted consists in maintaining the pieces of cast or forged steel at a continually uniform temperature in their entirety when they are once heated to the point where the transformation of the metal occurs and when flaws are liable to result.
>
> To realize this principle we submerge in a metallic bath composed of molten lead the pieces which have been heated, and we leave them to cool at will in this bath. Metallic baths, as is well known, possess a special conductivity, which is eminently superior to that of liquids—such as oil or water—and avoid also the production of vapor, which, in ordinary systems of tempering, spreads itself around the submerged piece and prevents the free transmission of heat.
>
> With our process the whole mass of the submerged piece is kept in a continual evenness of temperature with the bath itself, and the change in position of the molecules can go on freely in the interior of the piece, whether this change is the transformation of the grain of the metal or its contraction while cooling, and this

whole change is effected without interior tension. We obtain by this means absolutely perfect pieces, very regular in make, and which have given results in our different trials of them which are notably better than those obtained with pieces treated by the ordinary methods.

It must be remembered that this process, compared with the usual methods of forging, tempering, and reheating, requires, on account of its delicacy of treatment, a thorough knowledge of steel working and the condition of the steel to which it is applied. The temperature, of course, must be varied considerably, according to the kind of steel operated upon, as we have observed in our experimental researches that the composition of different steels and the accessory circumstances exert, on their side, a decided influence, which must not be neglected and which can not be appreciated without sufficient experience.

Guiding ourselves by the theoretical and experimental results thus obtained, we have been able to determine, for each nature of steel, the most appropriate application of our process and have obtained thereby the most satisfactory results.

Circumstances may be such as to make it expedient not to surpass the temperature of the fusion of lead.

In order to obtain the best results we found that a voluminous bath capable of submerging the largest pieces was necessary. It was then possible to vary the depth and space of the bath by the introduction of quantities of molten metal, which act at the same time as refrigerants. It will be understood that if parts only of the bath were to be allowed to cool and were then remelted for an ensuing operation, the continuity of the process would be destroyed and the process itself rendered impracticable.

The furnaces, which we use for melting the lead which serves for the immersion of the pieces, can be directly heated so as to permit the passing of the point of fusion, if necessary, and thus keep the bath at the desired temperature for the tempering process.

We have constructed a considerable outfit in order to insure facility, rapidity, and precision in handling large pieces. We have arranged machinery for the dipping of the pieces, filling in blocks, etc., allowing us to vary the form and level of the same. Finally, we have completed our plant by the adoption of optical instruments, allowing of an exact and rapid notation of temperature. It has been proved by our experimentation that the hardest of steels and metals of every composition treated according to our process are not subject to flaws in tempering. At the same time the grains of these steels were notably modified, and when the temperature of heating was correct the grains came out very fine and regular.

The tempering of a cannon gave us analogous results to that which is obtained by tempering with oil, followed by reheating. The tensile strength, and especially the resistance to shock of hard steel, was notably increased. This same result was also obtained with cast pieces.

This company received a gold medal.

Ice tempering.—At the works at Creusot ice tempering has been used to some extent with plates up to 2 inches thick, we understand.

SOCIÉTÉ ANONYME D'ÉCLAIRAGE AU GAZ ET DES HAUTS-FOURNEAUX ET FONDERIES DE MARSEILLE ET DES MINES DE PORTES ET SENECHAS, ST. LOUIS, MARSEILLE (BOUCHES-DU-RHÔNE), FRANCE.

This company exhibited pig-iron of various qualities, spiegeleisen, ferromanganese to 87 per cent. manganese, ferrosilicon to 14 per cent. silicon, silico spiegel to 14 per cent. silicon, and ferrochrome to 65 per cent. chromium, a long series of each variety.

This company was out of competition.

SOCIÉTÉ DES ACIÉRIES DE LONGWY, MORET-ST.-MARTIN (MEURTHE-ET-MOSELLE), FRANCE.

Origin, 1863; stock company, 1880; capital, 20,000,000 francs; one thousand five hundred and ninety-two employés and workman; six iron mines: seven blast furnaces; three basic converters, 15 tons each; rolling mills, shops, foundries, etc.

Product: Thomas pig-iron, 86,520 tons; other pig-iron, 22,722 tons; steel, all kinds, 70,653 tons; basic steel, 250 to 300 tons per day.

The iron ores range from 26 to 42 per cent. iron, the former calcareous, with 0.50 to 0.70 per cent. phosphorus and 0.10 to 0.30 sulphur.

The Thomas pig contains—

	White.	Mottled.
Manganese.	1.50	2.00
Carbon.	3.00	3.20
Silica	0.20	0.35
Sulphur	0.04	0.02
Phosphorus.	2.00	2.20

The phosphorus in the steel ranged from 0.05 to 0.10 per cent., with traces of sulphur. The basic slag contains 15 to 16.5 per cent. phosphoric acid, and 60 to 70 tons per day is produced.

The exhibits consisted of samples of raw material and products, ingots, blooms, billets, plates, rails, bars, forgings, etc.

This company received a grand prize.

COMPAGNIE DES MINES, FONDERIES ET FORGES D'ALAIS (GARD), FRANCE.

Capital, 9,000,000 francs; founded, 1830; iron and coal mines; six blast furnaces; Siemens-Martin furnace, puddling furnaces, rolling mills, hammers, and chain works.

The exhibit consisted of foundry pig, six classes; forge pig, four classes; spiegel 10 to 20 per cent. manganese; ferromanganese up to 80 per cent. manganese; ferrochrome 48 per cent. chromium; ferro-silicon 14 per cent. silicon; also iron and steel, rolled and cast in various forms; samples of ammonia and tar from coke ovens; system, Carves. The tar is rich in anthracene.

FORGES D'HENNEBOUT, HENNEBOUT (MORBIHAN), FRANCE.

The exhibit consisted of cast steel and iron, sheet iron and tin plates, stamped and decorated ware; very soft steel obtained in basic hearth furnaces, with magnesia brick linings; patent of Emile Muller, 1869.

VALTON-REMAURY, PARIS.

He exhibited neutral refractory materials, products resulting from their employment, and drawings of apparatus in which they were used. This is a process for the manufacture of steel and iron. As described by V. Deshays in Le Genie Civil, it consists in the use of chrome iron ore for beds and walls of open-hearth furnaces. It should contain 40 to 45 per cent. of chromium oxide. That from Greece, Asia Minor, and Sweden is best. The lumps are built in, using a mixture of limestone, as free from silica as possible, and the powdered ore as mortar, two of ore to one of limestone. Tar is used as a binding material for sides of charging doors and closing the tap-hole. On burning, the ore combines with the lime, forming a hard coherent mass, which does not fall to powder. None of the chromium passes into the bath of molten metal.

On starting, 6 to 10 cwt. of limestone are charged in when the furnace has reached the proper temperature, to protect the bed and provide lime for dephosphorization. An excess of limestone must always be employed. If there is sulphur in the pig, manganese ore must be added to the charge, giving six to seven times as much metallic manganese as sulphur. After the limestone has disintegrated, it is spread over the hearth, the pig and scrap being charged in. For a charge of 6.5 tons, 1.7 tons of pig and 0.6 tons of cast-iron scrap are charged in. When this is melted the preheated iron scrap is charged in 6 to 10 cwt. at a time. The slag is tapped as soon as possible and more scrap is added until the bath is quiet. To eliminate the last traces of phosphorus, balls of lime and hammerscale are added to the bath. The metal produced is very soft. (Valton-Remaury also recommend the use of this ore for basic converters and cupolas.)

This lining was first used by Compagnie des Mines, Fonderies et Forges d'Alais, in 1885.

SOCIÉTÉ ANONYME MITIS BELGE, HUY, BELGIUM.

The exhibit consisted of a great variety of castings of Mitis iron, Nordenfelt's patent.

The Mitis process is dependent upon the discovery by Wittenstroem, of Stockholm, and Nobel, of St. Petersburg, that the addition of a small quantity of aluminium to wrought iron, heated until pasty, causes the iron to liquefy at once, so that it can be poured into castings having all the properties of wrought iron except fiber, and as sound as cast-iron. The experiments were made in 1883 and 1884, and the manufacture of Mitis castings was commenced in 1885, in Nordenfelt's foundry, in Carsvick, Sweden, and Nobel's foundry, St. Petersburg.

The charge consists of wrought-iron scrap, if softest product is

desired, mixed with more or less steel scrap or cast-iron for harder products. The presence of phosphorus much above 0.1 per cent. is found to be injurious, and with scrap steel manganese interferes with the production of good castings. The furnace used is Nobel's petroleum furnace. The charge is placed in covered crucibles and heated to 2,200° C., the point of becoming pasty. Several hundred degrees increase of temperature would be required to melt the iron so as to be able to cast it without the addition of aluminium, during which time absorption of gases would take place and the consequent deterioration of the metal.

On adding to the charge, in the pasty condition, ferro-aluminium containing 8 per cent. aluminium, equivalent to 0.05 to 0.10 per cent. aluminium, the charge immediately liquefies and may be cast in molds of sand or iron. When the furnace is fully heated, the melting takes place in three-fourths of an hour.

The castings are smooth, ductile, may be forged and welded, have all the properties of wrought iron, and an increase in tensile strength. They may replace malleable iron castings.

Numerous analyses have failed to find any aluminium in the castings, and at most 0.02 per cent. have been detected. The explanations offered by various authorities of the action of aluminium are that the aluminium reduces the dissolved oxide of iron, which makes the charge pasty; that the evolution of gas ceases because the aluminium combines with all the oxygen present; and the greater fluidity of the metal allows the gases, entangled during the castings, to escape and thus lessens the blow-holes.

It is said that the process is in use in five American establishments, and abroad in Austria, Belgium, England, France, Germany, Russia, and Sweden.

GJERS, MILLS & CO., AYRESOME IRON WORKS, MIDDLESBROUGH, ENGLAND.

This company exhibited samples of foundry and hematite pig-iron, ferrosilicon and silicospiegel. Also models of blast furnace plant and Bessemer steel works with Gjers soaking pit and enlarged section of pit.

SILICOSPIEGEL—FERROSILICON.

Silicospiegel is used by steel founders for mixing with molten steel in the manufacture of solid steel castings, free from blow-holes; it is also used in place of ferromanganese, and has the effect of making the molten steel more fluid, and thus produces a cleaner casting. If an extra soft steel is required for special steel plates, silicospiegel is

used in place of ferromanganese, and the quantity to be used varies from 1½ to three-fourths per cent.; the extra quantity can only be arrived at by experience, and varies according to the quality of the steel used. The above remarks apply to silicospiegel, but, where ferrosilicon is used, ferromaganese must also have been previously used in the manufacture of the steel, and the quantity of ferrosilicon required is from 1 to three-fourths per cent. The best steel founders in this country prefer to use silicospiegel rather than ferrosilicon.

In steel casting the silicospiegel or ferrosilicon may either be put into the molten steel in a Siemens-Martin furnace, or it may be put into the ladle in which the steel is run from the furnace; and in the case of Bessemer steel, it is always put into the ladle. In the manufacture of crucible steel castings, the ferrosilicon or silicospiegel is put into the crucible in the proper percentage required for the purpose, and melted with the steel. Ferrosilicon is used by iron-founders where a soft fluid and solid casting is desired, and also where a large quantity of scrap or hard pig-iron is used containing a low percentage of silicon. The ferrosilicon is usually mixed and melted with the pig-iron in the cupola, and the quantity used varies from 2 to 5 per cent., and in case of hard iron even 10 per cent.

For steel castings it is found that the higher the percentage of silicon in the ferrosilicon and silicospiegel used, the more satisfactory the result.

Analysis of ferrosilicon, made at Ayresome Iron Works, Middlesbrough.

	Per cent.
Iron	84.39
Carbon	1.40
Manganese	2.10
Silicon	12.05
Sulphur	0.01
Phosphorus	0.04
Arsenic	trace
Copper	0.01
	100.00

Analysis of silicospiegel, made at Ayresome Iron Works, Middlesbrough.

	Per cent.
Iron	67.05
Carbon	1.39
Manganese	19.25
Silicon	12.25
Sulphur	trace
Phosphorus	0.05
Arsenic	trace
Copper	0.01
	100.00

GJERS' PATENT SOAKING PITS.

[Mr. Gjers' method of treating steel ingots.]

The system is briefly as follows: A number of upright pits (the number, say, of the ingots in a cast) are built in a mass of brickwork sunk in the ground below the level of the floor. These pits are commanded by an ingot crane, by preference so placed in relation to the blooming mill that the crane also commands the live rollers of the mill. Each pit is covered with a separate lid at the floor level, and

after having been well dried and brought to a red heat by the insertion of hot ingots, they are ready for operation. As soon as the ingots are stripped (and the molds should be removed as early as possible) they are transferred one by one, and placed separately by means of the crane into these previously heated pits (which Mr. Gjers calls "soaking pits"), and forthwith covered over with the lid, which practically excludes the air. In these pits, thus covered, the ingots are allowed to stand and soak; that is, the excessive molten heat of the interior, and any additional heat rendered sensible during complete solidification, but latent at the time of placing the ingots into the pit, becomes uniformly distributed, or nearly so, throughout the metallic mass. No heat, or comparatively little, being able to escape, as the ingot is surrounded by brick walls as hot as itself, it follows that the surface heat of the ingot is greatly increased; and after a space of from 20 to 30 minutes, according to circumstances, the ingot is lifted out of the pit apparently much hotter than when it went in, and is now swung round to the rolls by means of the crane in a perfect state of heat for rolling, with this additional advantage to the mill over an ingot heated in an ordinary furnace from a comparatively cold, that it is always certain to be at least as hot in the center as it is on the surface, and the heat is perfectly uniform. Much more, of course, needs to be said fully to describe this process and its advantages, but a careful study of the model, along with the brief hints given, will make the general principle sufficiently clear, and to those who are most interested in these matters the advantages of the process will be obvious. The operation of steel-making on a large scale is hereby very much simplified. A large number of men, some of them highly paid, are dispensed with, and the costly heating furnaces and gas generators so costly also in their maintenance are done away with. A saving is effected of the coal used in heating and still more in yield of steel, which in the heating furnace is very much wasted; moreover, the spoiling of steel by overheating in furnaces is completely done away with. Eminent experts and practical men, who had not only examined the process but carefully tested it in practical working, and that over a considerable period of time, speak of it in the highest terms, and it seems certain to work quite a revolution in the steel industry. We need only say further that the underground position of the soaking pits offers the best facility for handling the ingots with economy in labor, and, as an inspection of the model will show, there is no running the ingots about as is usually the case in steel works; they are lifted by one crane to another and directly into the pits. The cranes lift, swing, and rack in and out by hydraulic power, so that very little labor is required except what is needful for putting the dogs on to the ingots and remove and replace the lids.

W. F. Durfee states, in the Iron and Steel Bulletin, that the amount of steel passing through the Gjers' soaking pit was, in tons:

Country.	1887.	1888.
Great Britain.....	237,546	257,335
Germany.....	153,454	227,020
Austria	90,000	95,000
Belgium	68,162	67,377
France	8,223	22,558
Sweden.....	4,348	4,578
United States.....	.....	38,660
Total	561,733	712,528

SOCIÉTÉ ANONYME DES FORGES DE FRANCHE-COMTE, BESANÇON (DOUBS), FRANCE.

Founded 1853. Capital 18,741,500 francs. Number of workmen, 4,000. Produce iron and steel in blooms, bars, plates, and wire; axles, wheels, nails, tacks, rivets, etc.; iron wire coated with copper, tin, and zinc; tinned wire, 1,000 metres to the kilogramme; chains without welding, and angle iron. Product, about 70,000 tons of all kinds.

SOCIÉTÉ DES CHAÎNES EN ACIER SANS SOUDURES.

Process Oury.

An ingenious method of producing chains of all sizes and forms of steel without welding. These are made of fine rolled steel bars, a transverse section of which has the form of a cross, with arms of equal length. By machine punches, presses, and drills these bars are divided into the links of the chains. The government test shows increased strength over chains of same caliber of iron. The cost of production is said to be less than of those of iron.

SOCIÉTÉ DES ACIÉRIES D'ALEXANDROWSKY, ST. PETERSBURG, RUSSIA.

Founded in 1879 by a French company. Six hundred workmen. Six Siemens-Martin furnaces, 8 tons each, with neutral lining; one Siemens-Martin furnace, 13 tons, with acid lining; rolling mills, reheating furnaces, etc.

Product, 17,000 tons of ingots per annum; 10,000 tons of plates, bars, shapes, axles, wheels, tires, etc.

The premium offered by the government, together with the import duty, afford a protection to the works of 166 francs 50 centimes per ton of product.

SOCIÉTÉ ANONYME DE MÉTALLURGIE ET CONSTRUCTIONS, VIZCAYA. SESTAO, NEAR BILBAO, SPAIN.

Founded 1882. Capital 12,500,000 francs. Two blast furnaces, put in blast 1885; one blast furnace in construction; three Siemens-Martin furnaces, 12 tons each, commenced production May, 1889; one Siemens-Martin furnace in construction; seventy-two coke ovens in use 1885, system Carves, with utilization of by-products; seventy-two coke ovens in construction; rolling mills in operation June, 1889.

Product per annum, 150,000 tons of minerals; 60,000 tons of coke and by-products of tar and ammonia sulphate; 85,000 tons of hematite pig-iron, and 18,000 tons of soft steel.

About 50,000 tons of pig-iron have been exported per year.

This company received a grand prize.

ZINC.

LA SOCIÉTÉ DE LA VIEILLE-MONTAGNE.

From a pamphlet published by this society, the following statements are extracted:

The calamine deposits at Moresnet, Duchy of Limbourg, in Belgium, are the most famous and the oldest worked mines of this mineral mentioned. From the beginning of the middle ages this ore was taken thence for the production, in mixture with copper, of brasses. Orichalcos was manufactured by the ancient Greeks and, no doubt, the secret of its manufacture had reached Belgium through Germany. Under date of July 5, 1435, there is mention made of the concession of a mine of zinc by the duke of Limbourg. In one account of 1439, they mention the mountain of calamine, "which those of Aix had the habit of working." This mine, then abandoned, must have gone back to a far distant period. On account of this circumstance, this calamine deposit had received later the name of "Vieille-Montagne" (Altenberg).

In 1454 the mine was reopened, after the grant had been given by Philippe le Bon to Arnold Van Zevel. This mine, which must have had so long an existence, was from that time on the most esteemed for the abundance and quality of its products. The ore was calcined on the spot with charcoal from the forests of Hertogenwald, and carried to the different localities where copper was worked. It was in use at Aix, Stolberg, and Cornelius-Munster, but the manufacturers of brass of Dinant, Bouvignes, Oignies, and other localities of the county of Namm bought the greater part of the production and had it transported toward their factories, first as far as Viol and afterwards utilizing the water courses of the Meuse and the Sambre. It is known that they obtained brass by mixing in crucibles cala-

mine and coal with red copper from the Tyrol. Then they transformed the cast or hammered brass into objects of all kinds, of which the existing specimens attest a true art sentiment of the authors.

Under the Dukes of Limbourg and of Burgundy, as well as under the Spanish dominion, the mines of this region of Moresnet were sometimes conceded temporarily, leased to private parties, never exceeding 12 years, and sometimes worked for the account of the government by its functionaries. This last system was notably used under the Archduke, Albert and Isabella, and later in the time of Philip IV, King of Spain. In imitation of the Spanish sovereigns, the Austrian Government practiced sometimes the leasing, and sometimes administration. After the annexing of the Belgian provinces to France, in 1795, the Republican Government worked the mine of Vieille-Montagne for the good of the nation; but this system soon brought a great decline in the working. The Imperial Government renounced it and, in 1806, conceded the mine to the Liege chemist, the abbot Daniel Dony, with "the obligation of making proofs, which could be recognized as useful, of his ability to reduce, by aid of appropriate furnaces, calamine to the metallic state." Thus the Emperor, in a manner, ordered Dony to discover zinc, and although discoveries are rarely made by order, Dony obeyed and discovered zinc. It is known that chance had in this invention, like many others, as great a part as science and the perseverance of man.

The anecdote is classical; Dony tried to melt the calamine in a reverberatory furnace. Supposing the mineral was not sufficiently fusible to produce the desired reaction, he had the idea of mixing it with coal direct. Then, so as to observe what took place in the apparatus, he adjusted in the edge of the furnace a flower-pot, which projected in front of the masonry. What was his surprise to see soon, through the little hole in the bottom of the pot, the zinc condense in drops in that form of prolong, colder than the oven. The method of reducing the mineral of zinc was found, and one of the great modern industries was to come from that little workshop of the faubourg St. Leonard at Liège, where Dony had installed his rudimentary furnaces. The first step was taken; but in spite of the proverb, it was not that one which was to cost the most. It was not sufficient to have invented zinc, it was necessary also to find the means of using it; it was necessary to give the public the desire and the idea of utilizing it; it was necessary to raise the new comer to the rank of necessary metals. One man alone could not suffice for this task. Dony ruined himself and died without having accomplished it.

Dominique Mosselman succeeded him, in 1818. He was a man of rare energy. He consecrated his life to perfecting the manufacture of the new metal and to finding for it a market. But, nevertheless,

at his death, in 1837, this industry scarcely existed save in expectation. To mobilize his estate, his children founded the stock company of "Vieille-Montagne," with a capital of 7,000,000 francs, divided into seven thousand shares of 1,000 francs each.

The patrimony of Mosselman's heirs, which constituted the property of the new company, comprised the calamine mine of Moresnet, the zinc foundry of St. Leonard at Liège, two small rolling mills at Hom and Houx in France, and, finally, the factory at Angleur, on the borders of the Ourthe, then in course of construction. A few months later the company bought the rolling mills of Bray, in France, and of Tilff, in Belgium. Managed by two directors, one residing in Paris and the other in Liège, the company had a laborious beginning, and developed slowly, notwithstanding the efforts of eminent administrators. In 1846 the direction of affairs was confined to St. Paul de Sincay, who still manages them. From that moment the new company made a rapid advance.

In 1853 it absorbed the Companies of Rhenish Prussia, of Valentin-Cocq, and of the Meuse; added to its Belgian establishments the manufactures and coal mines of Valentin-Cocq and of Flöne; planted itself in Germany, with its mines of the district of Bensberg, its foundries at Bensberg and Mülheim, and its rolling mills and furnaces for roasting the blende of Oberhausen. In 1855 the Company for White Zinc disposed of all its property to this company, chiefly consisting of the factories for white at Brussels, at Levallois-Perret near Paris, and at Colladios. In 1857 the company, realizing the future for the treatment of blendes heretofore regarded as useless, purchased in Sweden the vast beds of the district of Ammeberg, near Lake Wettern. The same considerations determined them in 1889 to build large works for roasting blendes near Antwerp, on the canal of Campine. In 1871 the great discoveries of zinc ores in the Mediterranean Basin, which menaced the equilibrium of this industry, decided the company to purchase and develop a new center of production in France, at Viviez, and a rolling mill at Panchot; of assuring to itself, by deeds of purchase and by exploitation in shares, the product of important mines in Sardinia, in the district of Iglesias. After having obtained in Algeria the concession of Hamman, it has endeavored to extend there constantly its mining property in the interest of its French factories. In 1883 it bought in the Gard and the Hérault the mining concessions of the "Société des Zinc Français," in liquidation. Finally, in 1887, it has completed its facilities in France by acquiring in the department of the North, in the proximity of its reduction works, the rolling mill of Hautment. By its situation in the center of a net-work of communications by water and rail this establishment is destined to render great services to the important French customers of the company.

The "Vieille-Montagne" possesses twenty-one large establishments,

centers of administration of commerce and of metallurgical and mining production, disseminated in Belgium, France, Germany, Sweden. Sardinia, Spain, and Algeria. It has 250 technical and administrative employers and 6,500 workmen, not including those engaged in contract work. The salaries and annual payments amount to more than 8,000,000 francs. Its steam and hydraulic motors aggregate 4,500 horse-power, and are one hundred and eighty-five in number. In 1888 it sold 62,000 tons of zinc of all descriptions, cast, rolled, and oxide. It is so constituted as to its mines and manfactures that it can produce this large quantity, constituting an important part of the total production.

Notwithstanding the considerable amount of business indicated, the capital stock is only 9,000,000 francs, represented by 112,500 shares of a par value of 80 francs each. From time to time there has been issued 14,800,000 francs of bonds, of which 1,763,500 francs have been redeemed. The balance will be redeemed in 1892. Up to the end of 1888 the reserves of this company amounted to 43,648,613 francs. Since its origin it has paid annually in dividends an average of 20 per cent.

The Vieille-Montagne, the first in date, has remained the first in importance of the companies producing zinc ores. By its initiative it has largely contributed to the progress of this branch of mining industry. Its principal deposits—those of Moresnet for calamine, and those of Bensberg, on the Rhine, and Ammeberg, in Sweden, for blende—have become, in a manner, classical. More than 2,000,000 tons of ore have been produced by the first named. It is the most important of central Europe. In the north bed silicate of zinc is abundantly found, from which zinc almost chemically pure is made. The Sardinian mines have produced large quantities of good calamines.

The furnaces used are of two types—the Belgian and the Silesian. The Belgian was originally constructed with sixteen to twenty retorts, producing 200 kilogrammes of metal per 24 hours. In 1840, by uniting the furnaces by fours, the production increased to 250 and 300 kilogrammes. At the present time, with the same number of workmen and consumption of coal, the furnace of Anglem produces 1,300 to 1,400 kilogrammes. At Valentin-Cocq, the greatest zinc works of Europe with the Silesian system, the production is about the same. At Viviez gas stoves with a blast of air are used, whereby inferior coal is utilized.

In the manufacture of the retorts and fire-bricks the materials are pulverized, mixed, and kneaded by machinery, and subsequently by a machine formed into retorts. At some of the works a hydraulic press is used, especially adapted for the manufacture of the Silesian retort. These machines produce six times as many retorts of a superior quality with fewer workmen.

The ore is pulverized by the Vaport crusher, which crushes 12,000 kilogrammes per hour. The mixtures are transferred by machinery to the furnace fronts.

Uses of cast zinc produced by this company.—Zinc extra pure, made from the Moresnet mineral, is almost chemically pure, and is used for the manufacture of brass for cartridge-cases. The English and Russian Governments require very pure zinc, which has been obtained from the United States, from the Bergenport and Bertha Works. Vieille-Montagne now manufactures a zinc superior to these at a lower price, containing less than half a thousandth of foreign matter. The French Government has given important orders for this metal.

Zinc, called art cast, used for imitation bronze in Paris.

Zinc for brass-making.

Zinc for galvanizing: It is estimated that England alone consumes 35,000 tons per year for this purpose. England and Germany have long had a monopoly of this business. Other uses are for the numerous special alloys, as delta metal, white metal, etc.

Rolled zinc: The uses of rolled zinc are very numerous and increasing every day. The most important is for roofing, 6 to 7 kilogrammes per square metre. Slate weighs 25 kilogrammes for same area. A zinc roof properly laid will last indefinitely. The roof of St. Barthelemy at Liège dates from 1811, and is still in good condition. Special pamphlets upon this subject are published by the company. They have introduced the use, also, of shingles of zinc. Over 10 hectares of this roofing was used at the Exposition buildings. The shingles are made of the ordinary form, lengthened and lozenge shape, also with double edges. These are also used for the lining of houses.

Channeled zinc is used for temporary constructions and others, and does not deteriorate like galvanized iron.

Rolled zinc is used for sheathing of ships, both wooden and iron. The English Government has applied this to a number of their ships. Rolled zinc has been substituted for cast zinc for preventing the incrustation of steam boilers and the prevention of corrosion. The galvanic action established serves to obviate both of these conditions.

For fastening the rolled zinc upon ships zinc nails are employed, as the iron nails are too rapidly corroded. These nails, which are wrought cold, are used for other purposes, to avoid the staining which iron produces. Other uses are for stamping of cornices and other architectural ornaments, household utensils, vats for breweries, etc., tubes for the ventilation of mines, lining of packing boxes, plates for zincography, leaf zinc for application to wall papers and decoration, perforated zinc for sieves, zinc wire for use when the staining by iron is to be avoided, and elements for electric batteries.

Zinc white: This is all made by oxidizing the metallic zinc, the snow-white oxide being made from the Moresnet zinc. Inferior

qualities are made from ordinary zinc. These are sold in powder and also ground in oil. Germany, Holland, and America use the American process, which does not produce so white an oxide.

Gray stone is a mixture of the refuse zinc oxide and oxichloride of zinc, under the name of metallic cement, used for the restoration of old monuments. The Porte St. Denis, in Paris, has been thus restored.

Stony oxide: Oxide of zinc mixed with potassium silicate furnishes an incombustible paint, called silicate paint. Oxide of zinc is also used for manufacture of India rubber, pasteboard, enamels, in place of minium, in fine colors for artistic painting, for whitening laces, in making wafers, chemical matches, sealing wax for champagne, children's toys, silvering of mirrors, preparing straw hats, children's carriages, paper to cover eatables, white oilcloth, patent leather, artistic basketware, impressions upon materials, porcelain maps, military equipments, etc.

The total production of crude zinc in Europe in 1888 was 271,010 tons. Below is a list of the producers of more than 6,000 tons:

	Tons.		Tons.
Vieille-Montagne	52,446	Société Austro-Belge	9,277
Société de Silesie	23,261	C. Dumont et frères	8,890
Héritiers von Giesche	17,858	Compagnie Rhin-Nassau	7,700
Compagnie royale Asturienne	16,383	L. de Laminne	6,696
Duc d'Ugest	15,688	Vivian & Sons	6,608
Compagnie Stolberg	14,247	Comtesse Schaffgotsch	6,498
Comte H. Von Donnersmark	11,361		

In a table is given the price of spelter from 1837 to 1888, the highest price being in 1842, 82 francs per metric centner and the lowest in 1848, 34 francs per centner; in 1878, 42 francs, and 1888, 46 francs.

A book specially describing the practical work is published by this company.

SOCIÉTÉ ANONYME DES MINES ET FONDERIES DE ZINC ET DE PLOMB DE LA NOUVELLE-MONTAGNE, BELGIUM.

This company was founded in 1845. Its mines yield zinc sulphides and carbonates carrying lead, and its coal mines furnish the fuel for the roasting and reduction of these ores. The roasting is accomplished in eighteen double hearth Freiberg roasting furnaces, connected with four lead chambers, each of 6,000 cubic metres' capacity, for the conversion of the sulphurous vapors into sulphuric acid. The roasted zinc ores are reduced in Belgian furnaces, the lead contained in the residues from the distillation being recovered by washing. From the rich galenas, the lead is obtained by the roasting and reaction processes, is free from arsenic and antimony and suited for the manufacture of white lead. A portion of the spelter is rolled

for sheet zinc. The crucibles and retorts are made by hydraulic presses.

All the workmen are associated in a bank of relief, which, for a small portion of their pay, furnishes gratuitous medical attention and medicines and pecuniary relief in case of sickness or wounds. The company also contributes largely to this bank.

LOUIS CAHAIGNE ET CIE., RUE ST.-BERNARD, 42, PARIS, FRANCE.

This company exhibited chemically pure distilled zinc, applicable to electricity and all industries.

Photozincography and the manufacture of brass for cartridges has made some demand for a pure spelter. In this country the ore from Friedensville, Pennsylvania, and from the Bertha mine in North Carolina yields a metal quite free from impurity.

FURNACES HEATED BY GAS.

The application of gas for the distillation of zinc has been adopted in various parts of the world, with the advantage of great economy of labor.

In Europe the continuous system has been introduced, in which the air only is previously heated. In this practice the air is forced by a fan-blower through flues of fine clay tiles, placed beneath the benches of muffles, the flues being carried transversely beneath the retorts, and being heated by the waste gases which envelop the flues. The gas is obtained from ordinary producers, similar to those in use for Bessemer works, etc.; the bituminous coal being decomposed upon inclined grates with underlying layer of cinders. The gas is not previously heated, but is delivered into small mixing chambers, beneath each bench of muffles, where it meets the hot air.

Another method is to deliver the gas at one end, beneath the benches, and force in the cold air at different points, in quantities sufficient to maintain the required heat.

A third method is by the use of water gas, produced by the forcing of air and low-pressure steam over anthracite coal, affording a gas of the following composition:

	Per cent.
Carbonic oxide	23 to 26
Carbonic acid	1 to 3
Hydrogen	15 to 12
Marsh gas	1 to 2
Nitrogen	60 to 57
Total	100 to 100

Both the gas and the air are heated in Siemens' regenerative chambers, placed beneath the benches of muffles, the air being forced by fan blowers and the steam passing into the gas produces with

the air necessary to the maintenance of the oxidation of the coal. The pressure is equal to 2 to 3 inches of water pressure. In the Belgium system of muffles, the muffles are in three tiers only, and in the Silesian system, as usual only one tier of muffles. By the use of gas the economy of labor is very great.

COPPER.

SOCIÉTÉ MÉTALLURGIQUE DU CUIVRE, ÉQUILLES (VAUCLUSE). FRANCE.

Process, Manhes. Received a gold medal.

There is no metallurgical operation which consumes, relatively to the quantity of metal produced, so large a proportion of fuel as the reduction of copper ores, and for this reason this branch of metallurgy has quite exclusively been concentrated in Great Britain, at Swansea and Liverpool, where coal can be had at a low price. For a long time they have treated them by the Welsh process, the copper ores coming from all points of the globe.

The Welsh process, a long time in use, consists, according to the nature of the ores, of from six to eight successive operations of roasting and smelting to bring the crude ore to rough copper. All the operations are made in reverberatory furnaces, sometimes combined with cupola furnaces for the production of mattes. No important modification has been made in the Welsh process since its origin, and the metallurgy of copper has remained stationary and has not for a long time made any serious progress.

Percy, Rivot, and Le Play estimate that in this process the consumption of fuel is, at the least, from 16 to 18 tons of bituminous coal per ton of copper produced; such a consumption renders this industry impossible in all countries where fuel is expensive.

In 1878 Pierre Manhes, metallurgist at Lyons, and proprietor of the copper rolling mills at Vedenes (Vaucluse), France, wishing to introduce and establish in France the reduction of copper ores, undertook the study of an economical process, which, by diminishing considerably the proportion of fuel used, rendered this industry possible with advantageous conditions. This study had for its basis the use of the Bessemer converter.

The idea was not new; since 1867 several attempts have been made in this way, but without success, because they had confined themselves to casual experiments without order or preliminary studies. Manhes, on the contrary, established a small experimental works, where, by aid of Paul David as an associate, he undertook a series of experiments which required two years of constant work.

Toward the end of 1880 success was complete, the industrial process absolutely practical, and Manhes, with the coöperation of

friends established the company, the name of which is at the head of this article, and which commenced operations in October, 1881.

The plant consists of six shaft furnaces for smelting the ores, two cupolas for remelting mattes if necessary, six Manhes converters, and four reverberatories for refining.

The Manhes converter differs essentially from the Bessemer converter, such as is usually employed in the metallurgy of iron.

The power for blast, etc., consists of water power and steam power equal to 400 horse-power. Especially established to show the working of the process, these works are, however, capable of treating a large quanity of ores, which may be mined in France, where deposits of copper are not wanting, though hitherto but little mined.

The advantages of the process are the suppression of the roasters, and, by an extreme simplicity, the ore being reduced to copper by two operations:

(1) A crude smelting of the ore to produce a copper matte.

(2) This matte is poured into the converter, when, by an energetic oxidation, it is rapidly transformed to rough metal of 98 or 99 per cent. copper.

Iron, sulphur, and other ingredients serve as fuel and maintain the high temperature necessary.

The operation in the converter lasts 30 to 40 minutes and is easy of execution. The metal is refined in a reverberatory furnace.

According to Percy, Le Play, and Rivot, the consumption of fuel in the Welsh process is from 17 to 18 tons per ton of copper, and the hand labor from 65 to 70 francs. In these works the consumption of fuel does not exceed 1½ to 2 tons per ton of copper, and the hand labor is less than 25 francs. These figures suffice to show what enormous economy the Manhes process realizes, and it is important to add that they are not the result of a few experiments, but of the industrial working in all the works which have applied the process.

Another advantage is the rapidity of execution; instead of the large stocks which are necessitated by the long and numerous operations of the Welsh process, in this process there is, so to speak, no stock of materials in use, as the same day can be obtained nearly all the copper contained in the ores. This process can therefore be applied to the reduction of ores in all producing countries, no matter what may be the cost of fuel.

Many mines of copper are neglected through the difficulty of finding an easy and regular supply of ore. This process, by reducing considerably the rôle of fuel in the metallurgy of copper, by simplifying the operations, permits the pursuit of this industry advantageously in all mining countries. The use of this process has spread in the copper-producing countries, where it tends to replace the older methods of treatment. It is in actual use in the following places, in addition to the works named at the head of this article: Parrot Copper

Company, Butte City, Montana; Vivian & Sons, Swansea, Wales; Compagnie des Usines de Lota, Chili; Société Métallurgique Italienne, Leghorn, Italy; Compagnie des Mines de Röraas, Röraas, Norway; Société des Fonderies de Brastberg, Norway; Société Minière de' Jeres Lanteira, Spain. Other works are in course of construction or under consideration in different countries of Europe, Asia, America, and Australia.

Some months since, after long study, Manhes succeeded in applying the same process to the metallurgy of nickel by means of a few modifications. The reactions are the same as in the metallurgy of copper. Iron, sulphur, arsenic, and antimony, the usual impurities of nickel, are rapidly oxidized under the energetic action of the converter, and after a few minutes' blowing one obtains, either by the treatment of the mattes or of the smelting, a crude nickel of 90 to 96 per cent. of pure metal, and the refining of which becomes easy by the ordinary processes. The introduction of the Manhes process in the metallurgy of nickel is under consideration in several works, and it is probable that it will permit a notable reduction in the cost of a metal, susceptible of numerous applications in industry and the arts. The exhibit consisted of models of Manhes converter, both fixed and movable, and series of samples illustrating the extraction of copper and of nickel.

To the foregoing statements, obtained from a pamphlet issued by the company, is appended some extracts from a paper by Professor Egleston, of Columbia College, New York, published in the School of Mines Quarterly, May, 1885, describing the works of the Parrot Silver and Copper Company, Butte City, Montana.

The converters are cylinders of sheet iron, 0.60 metre high, rounded at the bottom by a circle 1 metre radius to a flat bottom 0.65 metre in diameter, and terminated at the top by an arch of 0.70 metre radius, to which a spout is attached 50 centimetres in diameter. The greatest diameter is 1.54 metres, and the height 1.44 metre. The lining is a mixture of three parts crushed quartz and one part fire clay, 30 centimetres thick on the bottom and lower part of the sides and 25 centimetres on the upper part; at the spout, 6 centimetres. The tuyères are drilled through the lining while soft; they are 12 millimetres in diameter, are perfectly horizontal 15 to 25 centimetres above the stamped bottom, and eighteen to twenty in number. The wind chest is of cast-iron, placed around the converter above the bottom. The converter, lined, has the capacity of an ordinary oil barrel. The shaft furnaces are 5 metres high and 1 metre in diameter at tuyères, which are three in number. The ores are quartzose sulphides and carbonates, containing 12 to 15 per cent. of copper. Each furnace treats 25 to 30 tons of ore in 24 hours and produces 4 tons of matte, containing 25 to 30 per cent. copper. The matte is remelted in a cupola or run directly from the shaft furnace

to the converter. One and a half to 2 tons are run in, filling the converter 20 centimetres from the bottom. The vessel is turned up and the process conducted as in the Bessemer process. The blast is seldom more than half an atmosphere. Coke is added to increase the heat of the converter. It requires 25 minutes to bring a 40 per cent. to a 73 per cent. matte, and 30 minutes to bring a 73 per cent. to 99 per cent. matte. The converter makes twenty-two to twenty-four blows per day. The matte is poured from the converter into a conical mold, remelted and retreated. The slags are remelted with the ore.

The black copper obtained from the converter contains at least 97 per cent. copper and is refined in a reverberatory furnace. The monthly product is 85 to 100 tons.

When they go directly from the first matte to blister copper, a few hundred pounds of coke are used in course of 24 hours to keep the converter sufficiently hot; but in running low-grade material to bring it up to 72 to 75 per cent., the sulphur generates sufficient heat. In order to give greater fluidity to the scorias, cast-iron containing manganese is added to the first matte. If the work is to be done in one operation, a 70 per cent. matte must be made in shaft furnace from the ore, and much advantage of the process is lost. Whether one or two operations in the converter shall be performed is entirely an economical question. The fuel used per ton of copper produced is 4.7 to 5.2 tons.

By the Welsh method 13 to 16 tons are used.

For works producing 100 tons of copper per month 70 men would be required. The total loss of copper is not over 1 per cent. of the copper used in the mattes.

The use of the process has extended slowly, as it is not often practicable to treat a matte of 33 per cent. copper in a single fusion. There is no difficulty with rich mattes. Arsenic, antimony, zinc, tin, and lead are easily separated by the process; but cobalt, nickel, and bismuth seem to concentrate in the copper.

CHAUDRONNERIE HYGIÉNIQUE.

Bimetallic copper and silver. Ch. Martin & Co., 7, Rue Bleue, Paris. System, Édouard Martin patent.

This table ware and cooking utensils are made from copper sheets coated with silver by "placage," the two metals being rolled together, giving a heavy coating of silver. It produces handsome ware at lower prices than the best electroplate.

This firm also exhibited threads bimetallic of steel with copper envelope of great resistance, for use in the arts.

L. Letrange & Co., 1 rue des Haudriettes, Paris, workers in metals, had a fine exhibit of lead, zinc, copper, German silver, bronzes, cupromanganese, and solders in sheets, ingots, etc.

Malleable bronze for cartridge cases is said to have a tensile strength of 112,000 pounds and elongation of 75 per cent.

SOCIÉTÉ ANONYME DU MÉTAL DELTA ET DES ALLIAGES MÉTALLIQUES

Capital, 1,200,000 francs; works at St. Denis (Seine) and at Liège, Belgium; manufacture metal delta, copper, brass, bronze, and various alloys.

The exhibits comprised ingots, billets, plates, bars, castings, forgings, stampings, tubes, etc. Metal delta is covered by patents of Alexander Dick, a Danish engineer, dated 1883, and subsequent. This company holds the patents for France, Belgium, and Holland. This is said to be an alloy of iron, zinc, and copper. The iron is alloyed with the zinc under a reducing influence, and this alloy is then alloyed with the copper, making an intimate homogeneous mixture claimed to be a chemical combination. It has a specific gravity of 8.4, melts at 950°, has a yellow color, at a dark red heat is as malleable as lead, does not oxidize.

Tests given in their statement:

	Tensile strength.	Elongation.
	Pounds.	*Per cent.*
Cast	53,200	28
Rolled	86,100	12

The price is given at 13 cents per pound.

The above alloy is probably mangenese bronze of copper, tin, and manganese.

MATHELIN AND GARNIER, RUE BOURSAULT, 26, PARIS.

This firm exhibited bronzes and products of same: Phosphor bronze, special process of G. Guillemin. They state that a sample of bronze copper 88, tin 12, zinc 2, had tensile strength 25,000 pounds and elongation of 5 to 7 per cent.; after treatment by their process the tensile strength was 39,000 pounds and the elongation 14 per cent.

The use of phosphor bronzes has much increased. The method of introducing the phosphorus varies. Sometimes the melted alloy is poured upon the phosphorus, placed in a ladle or other vessel. the phosphorus being covered by a perforated piece of refractory earthenware held in place so that the phosphorus may melt and be distributed throughout the mass; or it may be forced below the melted alloy in a sheet iron holder with the same object. The resulting metal is more compact, has a higher tensile strength, and is said to be less attacked by acid-vapors, etc. The phosphorus probably combines with the oxygen dissolved and a small portion may be in combination with the alloyed metals.

Metal Roma is another alloy made by this firm, a phosphomanganese bronze, composition not given; specific gravity 8·50, color of bronze, malleable hot and cold, does not oxidize, not attacked by salt or acidulated water. Tensile strength 49,000 pounds, elongation 29 per cent. These are their statements.

B. H. Cramp & Co., Philadelphia, manufacture manganese bronze, which has been used for the screws of a number of United States war vessels. The alloy used is of the grade Vesuvius manganese bronze. Test made at San Francisco showed elastic limit 28,300 pounds and tensile strength 42,500 pounds. Test made at Zurich, Switzerland, showed:

	Tensile strength.	Elongation.
	Pounds.	*Per cent.*
Gun steel	78,200	14
Common bronze	32,700	8
Manganese bronze	41,240	17

We understand these bronzes to be all castings. Rolled bars of Cramp's bronze showed elastic limit of 86,100 pounds, tensile strength 100,551 pounds, elongation 25 per cent.

I am unable to give the composition of this bronze; of another make the following composition has been furnished: Copper 88, tin 10, zinc 2, manganese 1½ to 2.

ESCHGER, GHESQUIÈRE ET CIE., BIACHE—ST.-VAAST (PAS-DE-CALAIS), FRANCE.

Works for the treatment of minerals of copper, argentiferous copper, and auriferous-argentiferous copper; of lead, argentiferous lead; auriferous-argentiferous lead; of silver and gold; of auriferous and argentiferous zinc; and of gold and silver alloys.

The annual product here is:

	Tons.
Copper	4,000
Zinc	200
Lead	600
Silver	35
Gold	0.5

There are rolling mills, hammers, etc., for working the metals into various forms. Copper, brass, German silver, and bronzes, in form of ingots, plates, rods and wire, lead and zinc in plates. Tubes of various kinds, copper apparatus for various industries, moneys of copper, bronze, nickel, silver, and gold, moneys to the amount of 239,000,000 francs have been produced here.

At Ougree, Belgium, another works of this company produces 4,500 tons of zinc annually. Here in 1866 they applied electricity

for the recovery of a portion of the useful metals which had passed into the residues.

ELECTROLYTIC PROCESS FOR REFINING COPPER.

We mention here this process which has come somewhat largely into use for producing pure copper for electrical purposes. The impure copper is cast in slabs and suspended in a solution of copper sulphate in water, 2 pounds to the gallon, acidified with one-half pound sulphuric acid. Thin sheet copper forms the cathodes, which are placed about 2 inches from the anode of impure copper. They reach to within 4 inches of the bottom of the tanks, leaving the space in which the impurities settle. The tanks are of wood lined with lead, which is protected again by matched boards. These tanks are 4 feet by 10 feet by 3 feet 6 inches deep, and arranged on different levels, so that the solution flows by siphon from bottom of one to top of the next and prevents the separation into layers. The two conducting rods are placed on one side, and upon these the cross rods of copper for supporting the anodes and cathodes rest. The impurities pass first into solution, except silver and gold, which fall with the mud in the bottom. The copper is deposited upon the cathode. The cost of refining copper by this method is estimated by Fontaine at £6 per ton.

This process is in use in several establishments in the United States.

SOCIÉTÉ ANONYME DES MINES ET FOUNDERIES DE PONT-GIBAUD.

At Coueon (Loire-Inférieure), France. Founded 1853. Capital, 7,000,000 francs.

Lead smelting works in which ores from Sardinia, Spain, and mines of Pontpeum, near Rennes, are worked. The lead is desilverized by the zinc process. Product, 14,000 tons of lead and 20,000 kilogrammes of fine silver per annum. They make 5,000 tons of lead and tin pipe, 3,600 tons of sheet lead, 3,600 tons of shot and bullets, 3,000 tons of white lead, and 2,000 tons of red lead; of copper, 3,000 tons of ingots, 3,000 tons of sheets, 1,000 tons of wire and bars; of brass, 3,000 tons of sheets and 1,200 tons of bars and wire; at Pont-Gibaud (Puy-de-Dôme), smelting works for argentiferous lead ores and other ores of silver and gold. The works are capable of producing 5,000 tons of lead and 12,000 kilogrammes of fine silver per year. Since 1853, 47,800 tons of lead and 162,500 kilogrammes of silver have been produced here.

The ore of the mines of Pont-Gibaud and Auzelles is galena with some iron pyrites and blende. It contains 46 per cent. lead and 1.65 kilogrammes silver per 1,000 kilogrammes; a ton of lead yields 3.58 kilogrammes of silver. The process of extraction of the silver is by use of zinc.

TIN.

CLEVELAND TIN MINING COMPANY, DEADWOOD, BLACK HILLS, DAKOTA.—HARNEY PEAK TIN MINING COMPANY, BLACK HILLS, DAKOTA.

These companies exhibited tin ore, cassiterite in quartz, and received bronze medals. In regard to the tin deposits of the United States, we append an extract from the Transactions of the New York Academy of Sciences, March, 1889, a discussion by Prof. J. S. Newberry of Columbia College:

The description of the tin deposits of North Carolina given by J. H. Furman has interested me exceedingly, from the parallelism it shows between the structure of that region and that of the tin-bearing districts of the Black Hills and other portions of the world. Tin is a metal that is very sparsely distributed. The great masses brought from Tasmania, shown at the Centennial Exhibition, were quite phenomenal, and it is not at all surprising that we do not find it in such masses here. It is still an open question whether tin can be profitably worked in the Black Hills; the quantity is enormous, and yet it remains to be seen whether metal enough can be got out of each cubic yard of those great veins to pay the cost. Certainly the conditions in North Carolina seem to be much more favorable.

The tin that has come to us from various parts of the world has all been taken from surface deposits, except that of Cornwall; there it has been regularly mined as iron and gold are mined; but all the tin brought from the island of Banca, from the Malay peninsula, and from Australia, is obtained by the working-over of gravel. The granite containing it has been largely carried away, and what remains is decomposed, so that the tin is obtained by washing. There, too, labor is very cheap. The Chinese do well at placer mining where Americans would starve.

I do not know whether we can ascertain how large a quantity of material has been taken from King's Mountain by erosion; but further north in the Alleghanies the rocks have been very largely removed. Where erosion has been less active, the rock has been rotted down to a depth of 30 to 60 feet, just as Professor Agassiz tells us that in Brazil the rocks are sometimes decomposed to the depth of 150 feet. If any such decay has affected the tin-bearing rocks of North Carolina, the ore could be cheaply worked out, if sufficient water were to be had.

I think we owe a great debt to Mr. Furman for his discovery, and for the very lucid description he has given us. That it is a true tin deposit there can be no question, but just how much it will be worth to us *is* a question.

This is a very different affair from the so-called tin-stone that was brought here from Virginia three or four years ago. A hundred pounds of it was sent to me, and we had it analyzed in the School of Mines, but never got any tin from it. Other parties have claimed that they found in it 20 per cent. of the metal. I have seen certificates from those who profess to be assayers, claiming large returns of tin from this rock. I do not believe that there is any tin in it at all. But this is a real tin deposit, and it may be that it will prove a productive one. I would like to ask about the water there.

Dr. LEDOUX. There is plenty of water in the creek 100 feet below, that being the watershed where the vein is.

The PRESIDENT. The lack of water may be a difficulty. I should like it if we could get there a head of 500 feet of water, as they do in California, where they cut

down gravel banks 100 feet high and make a handsome profit from gravel, of which a cublic yard will yield but 10 cents.

In this connection, I have to show you a very different style of tin ore which comes from Zacatecas, Mexico. One of our old students, Mr. Banks, has just come back from there, bringing many specimens and having examined a considerable territory, In that region there is some stream tin, but not like that found elsewhere. Generally it occurs in drops and knobs, with a fibrous internal structure, and the masses are of concretionary character. This is different; for it is distributed irregularly through a rhyolite rock that has been evidently very much digested with hot water. The quantity is often large, and yet there, as elsewhere, it is a problem whether there is any deposit that can be worked with profit. I think the general impression has been that it would not pay to do regular mining there. Probably the only way to obtain tin profitably is to employ the natives to wash it out, working the deposit as a placer.

Tin is not nearly so rare a material as it has been said to be. Lumps of cassiterite are often found in the gold gravels of Idaho, and there are veins of tin ore in the Temescal mine near Los Angeles, California; but Mr. Stokes spent a year there, and, after fairly testing the deposit, he came to the conclusion that it would not pay to work it. So we are not so very destitute of tin in North America, but the conditions for the profitable mining of it are peculiar. It must be where, if possible, nature has decomposed the rock; then labor must be cheap, if we are to come in competition with the sources of supply in Tasmania and elsewhere. The conditions described to us by Mr. Furman in North Carolina would appear to be favorable, and it seems as though the chances were better for working the deposits there than in other places.

In regard to the Black Hills, we have had a great variety of testimony. Mr. Bailey, who was one of the first heralds of the great deposit of tin there, has told his story in this room. He brought before the Academy a splendid series of specimens, and claimed that the deposits of tin from which they were taken were unparalleled; but, though that was several years ago, no tin has yet come to market from that region, even after the expenditure of much money and mining on a large scale. The attempt has not yet been a success there. This North Carolina deposit promises better than any I have known elsewhere in this country; and yet I think it a matter of doubt whether the rock can be worked with profit. The mass before us is an unusually rich specimen of ore, and there is tin enough in it to pay for crushing and washing; but a great deal of that sort of work is often done by nature; almost all gold mining depends for its success upon decomposition of the rock. The gold-bearing rock has been made ready for the hand of the washer by natural processes, otherwise it would not pay to work; and the same is generally true of tin.

NICKEL.

The most important exhibit of nickel ores was by the French Mining and Smelting Company "Le Nickel," whose mines are in New Caledonia, and in regard to whose operations some account will be found further on. Their ore is a hydrous silicate of nickel and magnesia, quite free from deleterious impurities. The same ore was also exhibited in the French colonial section from the same locality. In the Norwegian section the Ringerige Nickel Mines and Works in southern Norway exhibited their ore, a niccoliferous pyrites containing 3 to 5 per cent. nickel and cobalt. In the section of the United States the Oregon Nickel Company exhibited their ore. The Can-

adian Copper Company operate mines at Sudbury, Ontario, producing ores containing 2½ to 3½ per cent. of nickel and a small percentage of copper. In 1888 they are said to have mined nickel ore equivalent to 200,000 pounds of nickel. They produce a matte of copper and nickel which is shipped to Great Britain and Germany for refining.

Nickel has become within a few years an important metal. Hitherto its chief use was in alloys with copper and zinc in the German silvers, so called, for the manufacture of articles for the table and other purposes and for electroplating. Switzerland, Belgium, Servia, Germany, United States, and Brazil have issued coins of an alloy of copper and nickel. France and other European states have made ball cases for small arms of an alloy of copper and nickel. These consist of an alloy of copper 80 per cent., nickel 20 per cent., with small quantities of aluminium and manganese. This metal is pressed to shape cold and filled with lead and constitutes the projectile. It is stated that these projectiles at 100 metres' distance have passed through 70 centimetres of pine plank. The most recent application of nickel is in alloying with iron and steel, producing with the latter alloys of great usefulness, a description of which will be given later in this article.

LE NICKEL, 13 RUE LAFAYETTE, PARIS.

Stock company with capital of 12,720,000 francs. Established 1880. Its mines are located in New Caledonia; its smelting works at Noumea and Thio, New Caledonia; Erdington, England; Kirkintilloch, Scotland; Havre, France; and Iserlohn, Germany.

This company produces mattes of nickel and of cobalt, crude and refined nickel, oxide of nickel and of cobalt. Product in 1888, 10,000 tons of nickel and cobalt ores. In 1889 it will export 20,000 tons, and in 1890 30,000 tons.

The capacity of various works of this company per month is 500 tons of mattes, 200 tons of refined metal. Germany, Japan, and India buy nickel in form of cubes, America in form of grains, China cubes and cakes, and England cakes.

Previous to the discovery of the deposits of nickel ores in New Caledonia, nickel ores were obtained in Norway, Sweden, Hungary, and Pennsylvania. The total consumption of metal was estimated at 400 tons per annum. The ores were poor, from 2 to 4 per cent. of metal, and contained arsenic, antimony, cobalt, and other metals which rendered the process of refining expensive.

The price of nickel was from 12 to 15 francs per kilogramme.

The discovery of the deposits of New Caledonia, and the abundance and richness of the ore, its freedom from arsenic, antimony, cobalt, copper, and sulphur have resulted in greatly lowering the price of the metal, which at this writing is 5½ francs per kilogramme.

The ore is exported 8 to 12 per cent. nickel, and is easily reduced to mattes or casts.

In New Caledonia the ore is smelted in cupola furnaces, 10 metres high, with cold blast, using limestone, Sicilian sulphur, and New Castle (Australia) coke. The product is 8 to 10 tons of mattes per day, containing about nickel 60, iron 25, sulphur 15. The impurities are chiefly silicon and magnesium. Larger furnaces could, of course, be employed. A process of refining mattes, given to the writer by a manufacturer, consists in crushing the matte, mixing with lime and sand, and roasting in a reverberatory furnace; part of the sulphur and iron pass off in the slag, the resulting matte containing 80 to 90 per cent. nickel. Again crush and roast giving nickel oxide. This is ground, mixed with carbon and reduced in crucibles. This metal contains from 97 to 99 per cent. nickel. The refining is carried on in France, at Havre, which is the most important nickel refinery in the world.

CHRISTOFLE & CO., PARIS.

The nickel ores of New Caledonia are hydrosilicates of magnesia and nickel, free from sulphur, arsenic, antimony, copper, and cobalt. The iron is not combined with these but is concurrent in small veins and isolated nodules. There seem to be three distinct types, viz:

(1) Emerald green, compact and hard, containing 18 to 20 per cent. of nickel and 5 per cent. of water.

(2) Yellowish green, more friable, containing 12 to 18 per cent. of nickel and 10 to 15 per cent. of water.

(3) Bluish white, very friable and easy to crush, even beneath the finger, containing 6 to 8 per cent. nickel and 20 per cent. of water.

The ores, as imported into Europe, contain a mixture of these and show an average composition—

	Per cent.
Water	22
Silica	38
Peroxide of iron	7
Protoxide of nickel	18*
Magnesia	15
Total	100

A similar ore is found in Malaga, Spain, but generally with a lower percentage of nickel.

At the works of Christofle & Co., at St. Denis, near Paris, the process pursued is as follows, being either a wet process or by wet and dry processes: the ore, in a coarsely powdered condition, is smelted in a furnace with sulphur, so as to produce a matte containing nickel, iron, and a small percentage of copper in combination with sulphur, the other constituents passing off in the slag. This matte is pow-

* Equivalent to nickel, 14.

dered by means of stamps, vertical millstones, and a ball pulverizer. The pulverized ore is placed in a roasting furnace 10 metres in length, and gradually but slowly advanced from the flue end to the fire bridge, occupying 5 to 6 hours. To insure thorough roasting this roasted matte is passed once or twice through the pulverizer, and each time submitted to the roasting operation. The product is essentially sulphide of nickel and oxide of iron. The gases from the furnace are passed through a room, to deposit any suspended dust, before reaching the chimney.

Treatment by wet process.—The well pulverized and completely roasted matte is treated with hydrochloric acid in earthen jars of a capacity of 100 litres. These jars are placed in a water bath, heated by steam, and inclosed in a wooden chamber, tarred upon the exterior, with a conduit to conduct the gases to the chimney. Scrubbers are interposed to absorb the greater part of the hydrosulphuric and hydrochloric acids which are evolved.

The nickel and iron pass into the state of chlorides, which solution is decanted into large covered wooden tubs. The iron is peroxidized by chloride of lime and precipitated by carbonate of lime, the agitation being produced by an air blast. The whole mixture is transferred to large wooden tanks in which the precipitate settles, and the liquid is separated by decantation. It is then pumped to wooden reservoirs of 25,000 litres capacity; the oxide of iron mud is filtered and the filtrate added to the preceding.

The precipitation of oxide of nickel was formerly accomplished by lime water, but owing to the small solubility of lime in water, the volume required was so great that only 25 kilogrammes of oxide of nickel was obtained from these reservoirs. Where very pure oxide of nickel is not desired, milk of lime is used, which permits a larger proportion of the nickel solution. The precipitation is accelerated by agitation. This precipitate is allowed to settle, the clear liquor is decanted, and the precipitate filtered. The wet oxide is dried partly upon a drying floor above the calcining furnaces in which the drying is completed. It is then washed with warm water to remove the lime, and drained upon linen filters.

Treatment in mixed process.—In this process the ore is converted into a matte as in the preceding process; also the matte is similarly roasted, but the roasted matte is treated in a reverberatory so as to separate the major portion of the iron which passes off in the slag. The sulphide of nickel is treated with hydrochloric acid as in the previous process.

Reducing the oxide of nickel.—The damp oxide of nickel, after washing out the lime and dripping, is mixed with flour, or very fine coal, and converted into a homogeneous paste by the action of two cylinders in a trough for the subsequent formation of the cubes or grain nickel, as may be desired. For the formation of the cubes, the

paste is placed in rectangular cases and heated at moderate temperature, 150° to 180°, for a short time so as to compact the mixture. The cake thus formed, about 1 centimetre in thickness, is cut into cubes by knives, and dried in the oven for several hours, until no more water is given off. The cubes are then placed in graphite crucibles with some coal dust; six to eight of these crucibles are placed in a blast furnace, and completely covered with coal. Here the temperature is carried above that required for melting of copper for 7 to 8 hours. This temperature accomplishes the reduction of the oxide of nickel and merely a softening of the metal, so that the cubes preserve their form. This reducing furnace is run continuously for a month without stopping, the crucibles being removed, emptied, refilled and replaced in the furnace. The crucibles last about 8 days.

The crucibles are made from refractory fire clay and plumbago mixed with finely-pulverized graphite crucibles, which have already been used in melting operations. The mixture must have the most complete homogeneity and the crucibles are worked upon the ordinary potter's lathe by means of copper mandrils. They are then dried in the air for a long time, and then placed in a moderately warm room for 24 hours. They are 25 centimetres high, 15 centimetres diameter, and will contain 30 kilogrammes of metal. Their cost is 1.50 francs.

This firm are large manufacturers of white metal table ware, which is composed of copper, zinc, and nickel, about 15 per cent. nickel.

In the refining of nickel the Germans have used a small addition of magnesium, Fleitman's method, and the French a small quantity of aluminium added at time of casting. The crude metal sometimes contains oxide of nickel in noticeable amounts, besides carbon and iron.

NICKEL EXTRACTION.

The following is condensed from Mr. Liviche's description of the process of Christofle & Co.

Ores: New Caledonia:

6 to 20 Ni, 5 to 25 H_2O.

Analysis: H_2O 22, SiO_2 38, Fe_2O_3 7, MgO 15, NiO 18, Ni 14.15.

Process either wet or mixed. Ore smelted in low blast furnace with fluxes. Regulus of sulphides of Ni, Fe, Cu. Regulus broken, crushed in rolls, calcined in reverberatory, with low arch, bed 33 feet long, narrow, charge gradually advanced to fire end from flue end, must not clot, lasts 5 to 6 hours; two calcinations, mass crushed before each, product $NiS+Fe_2O_3$.

Wet way.—Digest the last in HCl, stoneware vessels, 20 gallons capacity, producing $NiCl_2+FeCl_2$; decant into wood tanks. Peroxidize $FeCl_2$ with $CaClO_2$, precipitate by $CaCO_3$, and settle in wood vat. Transfer to wooden reservoir of 5,000 gallons; filter, and wash iron mud. Add washing to last. Precipitate NiO by milk of lime, settle,

draw off clear liquor, filter, dry, calcine, wash out CaO with hot water, drain, mix with flour or powdered charcoal to paste. Heat last 150° to 180° C., cake four-tenths inch thick, divide in cubes, drive out water by heat. Pack in black-lead crucibles with powdered charcoal, heat 6 to 8 hours in ore furnace, six to eight crucibles, temperature of melted Cu. Cubes retain form as Ni.

Mixed method.—Regulus fused in reverberatory with SiO_2 to rid of iron giving purer NiS below slag, tap former out below and dissolve in HCl as before.

Dry method.—Used at St. Denis. Like mixed method, but fuse again in reverberatory, fluxes in proportion to remove last Fe, giving almost pure NiS; oxidize by calcination, and reduce, giving malleable metal.

Mostly used here as alloys. Standard, equal parts Ni and Cu.

German silver for spoons and forks contains 15 per cent. Zn, balance Ni and Cu; this is electroplated. (Proc. Civ. Eng., 89, 559, 1887.)

L'ÉPINE & CO., 64 RUE DE TURENNE, PARIS.

This firm manufacture refined nickel goods and articles of steel plated with nickel by "placage." From a pamphlet published by them, a few extracts are here appended.

The metal is refined by processes, devised by Fleitmann, of fusion, rolling, and annealing, whereby it is rendered malleable and capable of being worked in various ways. The elimination of the carbon, without absorbing oxygen, is accomplished by them, their metal showing a purity of 99 per cent. The density of cast nickel is given as 8.3 and rolled metal as 8.6. The fusing point is between 1,800° and 1,900° C. The breaking strain is 68 kilogrammes per square millimetre for tempered nickel and 46 kilogrammes for annealed metal. The elongation of tempered nickel is 4 per cent. and for annealed metal 38 per cent.

The high melting point, great tenacity, its resistance to oxidation and the action of many chemicals, its malleability and its great brilliancy when polished render it useful in many economical directions. Its principal use hitherto has been in the production of alloys, white metals, or German silvers, and for use as anodes in nickel plating. These anodes were generally cast, owing to the difficulty of refining the metal and rendering it malleable, and thus increasing the cost.

Among the articles exhibited by this firm are rolled and cast anodes. The former, sold at 7.5 francs per kilogramme, are somewhat more expensive, but dissolve slowly and regularly, whereas the cast anodes by their porosity and lack of homogeneity, more rapidly disintegrate and deposit particles in the bath, giving rise to considerable waste. The cast anodes also contain considerable quantity of carbon, which does not injure the whiteness of the galvanic deposit, but diminishes the content of nickel.

Rolled plates for manufacture of knives, spatulas, knife blades, harness ware, jewelry, etc., sold at 8 francs per kilogramme.

A hammered nickel dish for use in pharmacy, 55 centimetres diameter, 25 centimetres deep, about 7 kilogrammes in weight, and 40 litres capacity. This was wrought from one piece; its retail price was 160 francs.

Nickel wire 0.178 millimetre diameter, at 22 francs per kilogramme; 3 millimetres upward, at 10 francs per kilogramme.

Chemical apparatus, such as evaporating dishes and crucibles, cooking utensils, table ware and jewelry, nickel, plated with platinum, has also been produced by this firm, which would be a useful substitute for that expensive metal. Among other proposed applications is the terminating of the glassblowers blowing tubes with nickel to remedy the staining of the glass by oxide of iron from the blowing tubes.

Nickel-plated steel is produced under the patents of Fleitmann and Witte, who worked this process in 1880, this firm in 1883. A plate of nickel is placed on either side of a plate of soft steel, having rolling properties approaching those of the nickel, the whole is then heated and rolled. The plating is easily accomplished and well done, the proportion of nickel is varied from 2 to 25 per cent. on either side of the iron, for culinary articles 10 per cent. being used. This is used (when the price of solid nickel is an obstacle to its use) for culinary utensils, reflectors for lamps (for which it is suited, as the nickel is less affected than silver), knife handles, helmets, pen-holders, pencil cases, corset steels, preserve cans, table ware, etc. The plating is complete, and the two metals are perfectly welded, and superior to electroplate by nickel, which is porous and permits rusting to penetrate, and its polish is less durable.

Pure nickel or plated is not much worked upon wooden mandrels, but better upon cast mandrels. The metals are stamped well by machine, being smoothed on the lathe after annealing. They also work well under the hammer with proper annealing.

The prices of some of the manufactured articles are appended:

Articles.	Nickel.	Plated.
	Francs.	*Francs.*
Casserole, 18 centimetres diameter	18	10
Sauce pans, 14 centimetres diameter	14	9
Coffee pots, filter, 4 cups	16	12
Soup tureen, 24 centimetres diameter	40	.....
Vegetable dishes, 24 centimetres diameter	38	20
Platters, 40 centimetres oval	20	11
Crucibles with cover, 10 centimetres diameter	6.25	.....
Double spatula, 21 centimetres	2.75	.....

Iron sheets, 5 per cent. nickel on each side, per kilogramme 2.80 francs.

Schoellen & Co., Vienna, also manufacture solid nickel goods. Special alloy for spoons: Copper, 45; nickel, 30; zinc, 15.

"LE FERRO-NICKEL," 17 RUE DU PONT-AUX-CHOUX, PARIS.

Stock company. Capital, 1,500,000 francs. Works at Lizy-sur-Ourcq (Seine et Marne), France.

Under the title of "Fonderie de Nickel et Métaux blancs," this company was established in 1882, by stockholders of the Company "Le Nickel," to extend the use of nickel in the arts and increase thus the consumption of this metal. They engaged in the manufacture of white metal and German silver. In 1883 they secured the patents for producing malleable nickel and cobalt and alloys of iron with nickel or cobalt. In 1884 the present name was adopted. In 1885 iron German silver was introduced, an alloy of greater resistance and elasticity, and of reduced cost. In 1886 an alloy of 80 per cent. copper and 20 per cent. nickel, with small quantities of aluminium and manganese, was made for the covering of balls for small arms, for use of the French Government. This metal is pressed to shape cold, and filled with lead. It is a very hard alloy, said to have penetrated, as a projectile, 70 centimetres of pine plank. In 1887 the manufacture of ferronickel was determined upon. This alloy consists of iron 75 per cent., and nickel 25 per cent. This company produces the iron and nickel alloys under the patents of Mr. Marbeau for the "production of ferronickel and ferrocobalt, by the direct employment of pigs or mattes of these metals with ferrocyanide or cyanide of potassium and one of the oxides of manganese, adding at the moment of casting a small quantity of aluminium." Contrary to the statement made during the discussion of Mr. Riley's paper, the above alloy is not attracted by the magnet.

ALLOYS OF NICKEL AND STEEL.

In a paper read by James Riley before the Iron and Steel Institute, at Glasgow, in May, 1889, are stated some results of his examination of alloys of nickel and steel, which were brought to his attention by Mr. Marbeau, the patentee, and also president of the Ferro-Nickel Company. A summary is here given: The composition of the metal can be as effectually controlled in the open-hearth furnace as in the crucible, and in as short a time as an ordinary charge of scrap steel, about 7 hours. No extraordinary care, nor any special arrangements for casting are required, and nearly all the nickel will be found in the steel, almost none being lost in the slag. The steel is steady in the mold, is more fluid, sets more rapidly, and appears homogeneous. Any scrap produced can be remelted in another charge without loss of nickel. No extraordinary care is necessary in reheating the ingots for hammering or rolling. If the steel has been

properly made and of the correct composition it will hammer and roll well, whether it contains little or much nickel. As with other varieties of steel, variation of the contents of other elements will exert considerable influence upon the character of the alloy. Up to 5 per cent. nickel the alloys can be machined with moderate ease; beyond that they are more difficult to machine. Up to 20 per cent. nickel has a hardening influence; at this point and beyond the addition of nickel tends to make the steel softer and more ductile, and even to neutralize the influence of carbon.

Compared with ordinary mild steel: Carbon, 0.22; elastic limit, 16 tons; breaking strain, 30 tons; extension, 23 per cent. on 8 inches, and contraction of area, 48 per cent. By the addition of 4.7 per cent. nickel, the carbon remaining the same, the alloy had elastic limit, 28 tons; breaking strain, 40.6; extension, 20 per cent., and contraction of area 44.8 per cent. Similar results followed with only 3 per cent. nickel.

With 25 per cent. of nickel the elastic limit was 15.1 tons; the breaking strain, 42.1 tons; extension, 40 per cent., and contraction of area 43.6. This great extension before fracture, indicating great ductility, is remarkable. The elongation is also nearly uniform throughout the piece.

One sample alloy furnished by the patentee gave breaking strain, 95.6 tons; elastic limit, 54 tons; extension in 4 inches, 9.37 per cent.; contraction of area, 49.2 per cent. The torsion tests were also good.

Nickel steels up to 50 per cent. nickel take a good polish, the color being lighter with increase of nickel. The corrodibility is less than with other steels. Compared with mild steel, 5 per cent. nickel steel corrodes in the ratio of 10 to 12; 25 per cent. nickel steel in the ratio of 10 to 870, which is practically in non-corrodible.

One per cent. nickel steel welds fairly well; but this quality deteriorates with addition of nickel.

Specific gravity nickel	8.86
25 per cent. ferronickel	8.08
10 per cent. nickel	7.866
5 per cent. nickel	7.846
Hammered steel	7.84

The uses to which these nickel steels may be applied are very numerous. The 25 per cent. nickel steel, or ferronickel, as the patentee calls it, by its great ductility and non-corrodibility will have many applications. Twenty-six thousand metres of wire per kilogramme have been drawn of this alloy. Its electrical resistance is much greater than that of German silver—about threefold. It may be used for small boilers, fire-boxes, and hulls of torpedo boats, requiring lightness, strength, and non-corrodibility, and between 25 and 5 per cent. nickel, may be found tool steel of good quality. With alloys of 5 per cent. and under, the marine and civil engineer

and ship builder will find many useful qualities, the greater strength enabling them to reduce the weight of materials used.

In the subsequent discussion it was stated by J. F. Hall, of Sheffield, who has been experimenting with these alloys, that high nickel steel had been used by him in making gun-barrels with good results.

In reference to the addition of nickel to cast-iron, Mr. Geny stated that the strength of the metal was increased, also its fluidity, resistance, and soundness. Armor plates 6 inches thick have been cast in nickel alloys.

The present writer understands that the Creusot works will submit a 5 per cent. nickel steel armor plate at the coming trial of the United States Navy Department.

Joseph Wharton, of Philadelphia, Pennsylvania, exhibited alloys of nickel and tungsten, an examination of which by Prof. John Trobridge and Samuel Sheldon, of Cambridge, Massachusetts, shows an increase over nickel in specific magnetism when magnetized to saturation. The nickel was of Mr. Wharton's manufacture, about 99 per cent. nickel. The results were as follows:

Bars rolled from cast ingots.

Nickel.	Tungsten.	Specific magnetism.
100	0	1.23
97	3	10.60
96	4	10.40
92	8	5.25
Tool steel.		7.46

Bars cast, not rolled.

Nickel.	Tungsten.	Specific magnetism.
100	0	1.05
99	1	1.92
98	2	1.70
97	3	1.75
94	4	1.15

The specific magnetism of good steel magnets is given as 40.

These alloys will form a useful addition to the resources of physical laboratories.

PATENTS FOR MANUFACTURE OF IRON AND NICKEL ALLOYS.

UNITED STATES PATENT OFFICE.

HENRI SCHNEIDER, OF LE CREUZOT, FRANCE.—PROCESS OF MANUFACTURING THE ALLOYS OF CAST-IRON AND NICKEL.

Specification forming part of Letters Patent No. 415657, dated November 19, 1889.

Application filed December 3, 1888. Serial No. 292520. (Specimens.)

To all whom it may concern:

Be it known that I, Henri Schneider, manager of the firm Schneider & Cie., of Le Creuzot, (Saône-et-Loire,) in the Republic of France, manufacturers, have invented improvements in manufacturing the alloys of cast-iron and nickel, of which the following is a specification.

This invention has reference to the manufacture on a commercial scale of cast or pig iron alloyed with nickel.

Many experiments have heretofore been made with alloys of iron or steel and nickel, and it is known that the addition of a small proportion of the latter metal to the former imparts thereto properties very valuable for certain uses. It is, however, extremely difficult to incorporate nickel with iron and steel, particularly when it is attempted to produce these alloys on a commercial scale. I have discovered that such alloys can be produced by making, as a preliminary product, an alloy or compound of cast-iron and nickel in a crucible, cupola, or open-hearth furnace. This product or alloy, while specially useful for the manufacture of iron and nickel and steel and nickel alloys, may be used for castings for a variety of purposes, and the present application is confined to the production of the cast-iron alloy.

The manufacture of alloys of nickel and steel forms the subject-matter of another application filed December 3, 1888, Serial No. 292518.

In carrying out my invention I charge a suitable furnace with nickel filings or scrap or waste nickel and ordinary cast or pig iron with carbonaceous matter; or the nickel may be in the form of nickelized compounds or coke. The operation may advantageously be carried on in a reverberatory furnace under a layer of anthracite to avoid oxidation. The alloy, which issues as a direct product of the furnace, contains from 5 to 30 per cent. of nickel (though the invention is not limited to these proportions), and is remarkable for its great elasticity and strength, and also for a true tenacity and malleability—properties which may be still further developed by chilling or tempering in well-known ways. The alloys are consequently suitable for use in the manufacture of castings of all descriptions, and to the production of armor-plates, projectiles, and the like.

I claim as my invention—

1. The herein-described process of manufacturing alloys of cast-iron and nickel by charging a suitable furnace with cast or pig iron, nickel, or a composition containing nickel, and melting together, as set forth.

2. The herein-described process of manufacturing alloys of cast-iron and nickel by charging a suitable furnace with cast or pig iron, nickel, or a nickel compound, and carbonaceous matter, with a superposed layer of anthracite, and melting together, as set forth.

3. The herein-described alloy of cast-iron and nickel rich in the latter metal, said alloy being distinguished by homogeneity, tenacity, capacity for tempering, and by the other characteristics set forth.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

HENRI SCHNEIDER.

Witnesses:

CHARLES BRÉNOY,

LÉON FRANCKEN.

UNITED STATES PATENT OFFICE.

HENRI SCHNEIDER, OF LE CREUZOT, FRANCE.—PROCESS OF MANUFACTURING THE ALLOYS OF STEEL AND NICKEL.

Specification forming part of Letters Patent No. 415,655, dated November 19, 1889.

Application filed December 3, 1888. Serial No. 292,518. (No specimens.)

To all whom it may concern:

Be it known that I, Henri Schneider, manager of the firm Schneider & Cie., of Le Creuzot, (Saône-et-Loire,) in the Republic of France, manufacturers, have invented Improvements in the Process of Manufacturing the Alloys of Steel and Nickel, of which the following is a specification.

This invention relates to the manufacture on the hearth or bed of a furnace, as hereinafter described, of steel alloyed with nickel, whereby a product is obtained which is employed in the construction of ordnance, armor plates, gun-barrels, projectiles, and other articles for military or other like purposes—commercial sheets or bars, for example. In order to manufacture this combination or alloy of steel and nickel upon a bed or hearth in such a manner as to obtain a homogeneous steel free from flaws or hollows, it is necessary, on the one hand, to avoid oxidizing the nickel before it forms the alloy with the iron, and, on the other hand, it is necessary to cause the incorporation to take place at as early a stage as possible in the operation, or immediately on the commencement of the fusion or liquefaction. This result is attained, according to this invention, by introducing the nickel by the aid of a preliminary melt or mixture in fusion, containing, say, for example, about thirty per cent. of nickel, sixty-three per cent. of iron, three per cent. of carbon, and two of manganese and silicon, this melt being placed on the hearth or bed of the furnace together with a suitable proportion of iron or scrap-steel.

In my concurrent application of even date, Serial No. 292,520, I have described the production of an alloy of cast-iron and nickel. This alloy may be used in the production of an alloy of steel and nickel, either while yet in the molten condition or after cooling and hardening. The alloy of cast-iron and nickel, instead of being formed separately, may be formed in the furnace before proceeding with the subsequent operations, though it is preferred to form it separately. In case it is formed in the furnace itself a bed of anthracite is first prepared in the furnace and the nickel is placed thereon with the requisite proportion of iron or steel. The whole is then covered with anthracite in order to protect the metal from contact with the air during the fusion. When the charge is melted, the excess of anthracite is removed and charges of iron or scrap are added in succession. Waste or scrap steel alloyed with nickel obtained by preceding operations is to be employed in these charges preferably in the first. From this time the operation is conducted on the hearth or open furnace in the same way as in making ordinary steel, care being at the same time taken to continually protect the bath from oxidation by means of a layer of slag or cinder, which is renewed as required, and also to take precautions to prevent redshortness in the metal before the final introduction of the recarbonizing and manganiferous silico-spiegel iron or ferromanganese.

The steel manufactured according to this invention usually contains about five per cent. of nickel—a quantity sufficient to impart a remarkable degree of strength to the product; but the invention is not limited to this proportion.

Steel alloyed with nickel according to this invention is especially adapted or suitable for use in the construction of ordnance, armor plates, gun-barrels, projectiles, and other articles employed for military or other like purposes, or the manufacture of commercial sheets, bars, and the like. The percentages of carbon, silicon, and manganese can be regulated according to the degree of hardness required; but in

all cases, in order to obtain the best result possible, the product must invariably be tempered in an oil or other bath.

I claim as my invention—

The herein-described process of manufacturing a homogeneous alloy of steel and nickel by first forming an alloy of cast-iron and nickel rich in the latter metal, as specified, and charging such alloy into a furnace of the character indicated, with the usual ingredients for the production of steel, and continuing the operation in the ordinary way, as set forth.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

HENRI SCHNEIDER.

Witnesses:
CHARLES BRÈNOY,
LÉON FRANCKEN.

UNITED STATES PATENT OFFICE.

HENRY MARBEAU, OF PARIS, FRANCE, ASSIGNOR TO THE SOCIÉTÉ ANONYME LE FERRO-NICKEL, OF SAME PLACE.—PROCESS OF MANUFACTURING IRON AND STEEL ALLOYS.

Specification forming part of Letters Patent No. 419,274, dated January 14, 1890.

Application filed April 8, 1889. Serial No. 306,432. (No specimens.)

To all whom it may concern:

Be it known that I, Henry Marbeau, of Paris, in the Republic of France, have invented a certain new and useful Improvement in the Process of Manufacturing Iron and Steel Alloys, of which the following specification is a full, clear, and exact description.

The invention relates to the production of malleable alloys of iron and steel with nickel and other metals.

Heretofore I have obtained ferro-nickels and steel nickels with a high percentage of nickel, varying from ninety-nine per cent. to twenty-five per cent. of nickel, possessing the peculiar properties of the latter metal, such as brilliancy, incapability of oxidation, &c., and which are capable of being substituted for nickel for many purposes. A description of the process of manufacturing such alloys is given in British Patent No. 7,179, dated June 12, 1885. In pursuing experiments in this direction I have now succeeded, by reducing the percentage of nickel below twenty-five per cent., in producing a series of alloys which, although belonging to the same class as those formerly described and patented, are possessed, on account of their constitutive elements and mode of production, of new properties, and constitute a distinct class of alloys, forming a new manufacture.

The present invention relates not to alloys of a relatively high price, which might replace pure nickel, owing to their richness in nickel, but to alloys which may be compared to iron and steel, and in which the addition of a proportion even small of nickel modifies the structure or constitution of the metal without materially augmenting its cost, (for the low percentages,) and produces a remarkable improvement in the quality of the iron or steel employed.

The present invention has for its object the production of malleable alloys of iron or steel with nickel in a proportion varying from about twenty-five per cent. down to a mere trace of nickel, these alloys being capable of being employed in the same way as iron and steel of commerce, but possessing superior qualities to those metals as heretofore obtained.

The new processes consist in simultaneously using manganese and aluminium with or without the addition of charcoal or other form of carbon or metallic cyanides or ferro-cyanides. With regard to manganese, either pure manganese is em-

ployed or oxides of this metal mixed with a reducing agent or ferro-manganese. In the same manner, with regard to the aluminium, either pure aluminium is employed or a mixture of iron and aluminium. The nickel itself is introduced either in the form of pure nickel or in that of a malleabilized metal, or in the form of a matt or speiss more or less rich in nickel, derived from the smelting of metal ores carried on up to the beginning of the elimination of iron or derived from a previous melting of cast or other iron or steel with nickel.

The following is an example of a convenient method of conducting the process in order to obtain a good result: It is preferable to take the nickel pure or alloyed with iron at the first stage of the operation. The manganese, in whatever shape it is used, mixed or not mixed with the carburizing agents, is added, either all at once or in two or more successive additions during the course of the fusion. The necessary proportion of aluminium is thrown in at the end of the operation, either in the melted metal in the furnace or in the casting-ladle. As regards the melting apparatus, any suitable apparatus—such as those used at the present time for metallurgical purposes, crucibles, reverberating furnaces, converters, Siemens furnace, cupolas, and the like—can be employed.

The following may be taken as an example of the proportions which may be employed with good effect; but the invention is not limited to the precise proportions specified: For every thousand parts, by weight, alloy to be produced, take from about one-tenth of a part to about one part of aluminium and from about one to twenty parts of manganese, according to the proportion of nickel and the quality of the product to be manufactured.

With regard to the carburizing agents, the carbon or cyanides are to be used in different proportions, according to the nature of the alloys required—that is to say, according as the alloys to be produced are hard or soft, carburized or not carburized, with the same percentage of nickel. Thus it is by the use of ferro-cyanide with manganese and aluminium, even without the addition of nickel, iron can be transformed into ready-tempered steel, capable of being forged directly into turning-tools without further tempering.

As an example, the proportions hereinafter specified are suitable for making on an open hearth a ferro-nickel with five per cent. of nickel, starting from a nickeliferous melt.

The operation is conducted as in making steel, and after the partial or complete decarburation (according to the quality of the alloy to be obtained) the metallic manganese or ferro-manganese is added, and when the time comes for running, the aluminium is thrown in, either in the open hearth or in the casting-ladle.

In order to make five hundred kilos (or thereabout) of alloy, the following may be used:

	Kilos.
Iron containing twenty-five per cent. of nickel	100
Soft iron or steel	400
Ferro-manganese containing seventy-five per cent. of manganese	3
Aluminium	.250
	503.250

The characteristic points of these different alloys are as follows: They possess a much more perfect homogeneousness than iron or steel obtained by the usual processes, and consequently they have very superior qualities, such as those of malleability, ductility, resistance, and elasticity. The ingots solidify very quickly, and blow-holes are avoided. Ferro-nickels with twenty-five per cent. nickel cannot be tempered whatever may be the proportion of carbon they contain; but in proportion as the quantity of nickel is reduced their capacity for being tempered increases,

and with a percentage of seven, five, and three of nickel and downward alloys are obtained which can be tempered just in the same manner as ordinary steels and according to the same rules.

The percentage of carbon, the distribution and the special forms of carbon in the cement and metallic nucleus, which modifications are due to the presence of nickel, (the cement referred to being the part containing the greater part of the carbon and surrounding the nucleus, which is constituted chiefly by the iron,) the fall of temperature between the heating and cooling, the rapidity of the cooling intervene to produce different qualities of hardness, as could have been foreseen from the complete analysis made according to the very accurate methods recently discovered and from the remarkable discoveries relating to the innermost constitution of the steel which have been made in the last few years.

The influence of the agents of malleabilization in the application of our processes is demonstrated by the fact that even when these agents are used without addition of nickel the products obtained possess qualities by far superior to those of iron and steel made by the ordinary processes.

Heretofore and prior to this invention I have produced ferro-nickel and ferro-cobalt by the direct fusion of pigs or mattes with one of the oxides of manganese and cyanide or ferro-cyanide of potassium, adding at the moment of tapping a small quantity of aluminium. Such process is described and claimed in British Patent No. 2,573 of 1884, granted on a communication from me. That process, however, related exclusively to the treatment of pigs or mattes of nickel and cobalt, whereas the process herein described is particularly applicable to pure or refined nickel. The former process related exclusively to alloys resembling nickel in their properties and containing upward of twenty-five per cent. of that metal, whereas the present invention relates exclusively to alloys containing less than twenty-five per cent. of nickel and from that down to a mere trace, such alloys constituting, as already stated, an entirely distinct class, possessing different and peculiar properties. Moreover, by the present invention a great economy is effected in the agents of malleabilization, and the new process differs radically from the former one in the proportions of these ingredients. I employ, according to the present invention, about one-ninth the quantity of manganese, about one-half the quantity of aluminium, and a much smaller proportion of carburizing agents to the same quantity, by weight, of the alloy.

I claim as my invention—

1. The herein-described process of manufacturing malleable alloys containing iron or steel and nickel by fusing the iron or steel with a comparatively small proportion (less than twenty-five per cent.) of nickel and with manganese and aluminium in approximately the proportions stated, as set forth.

2. The herein-described malleable alloy, composed of iron or steel and nickel, the proportion of nickel being less than twenty-five per cent. of the whole, with manganese and aluminium in approximately the proportions set forth.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

HENRY MARBEAU.

Witnesses:
MAURICE GENZ,
JOSEPH BOURNIER.

ALUMINIUM.

ALUMINIUM COMPANY, LIMITED, LONDON, ENGLAND.

Founded in 1887. Capital £400,000. Works at Oldbury near Birmingham. This company exhibits aluminium and its alloys, sodium and potassium.

They produce sodium and potassium by the patented processes of H. G. Castner, of New York. They have also acquired the patents of James Webster, for the production of pure aluminium and its compounds. Aluminium is produced by the Deville process modified by various improvements. This modified process has been styled by Sir Henry Roscoe, Deville-Castner process.

The exhibits of this company consisted of a block of 98 per cent. aluminium weighing half a ton, and a block of aluminium bronze of the same weight. Also ingots of of 99 per cent. aluminum, 5 and 10 per cent. bronze, 10 per cent. ferroaluminium and 20 per cent. aluminium steel. Also aluminium plate, sheets, wire, tubes, statue, cigarette cases, etc.

This company received a gold medal.

By the old process of making sodium, carbonate of soda, charcoal, and lime in the proportion of 30, 13, and 7 are brought into intimate mixture, calcined at a red heat to render it more compact, and distilled in narrow wrought-iron cylinders at 1,400° C., the metal passing off as vapor through small tubes to the condenser. Only 40 per cent. of the theoretical product is obtained, in the case of potassium much less, and the wear and tear of the cylinders is very great.

A black compound by the action of carbonic oxide upon the metallic vapor closes the small tubes; in the case of potassium this is explosive, requiring constant attention. The cost is as follows:

	s.	*d.*
Materials, owing to loss	1	0
Wear and tear of furnace, etc	2	0
Labor	0	8
Fuel	0	4
Sodium per pound	4	0

THE CASTNER PROCESS.

The process for the production of sodium and potassium is represented by the following equations:

$$6\,NaOH + FeC_2 = 2\,Na + 2\,Na_2CO_3 + 6\,H + Fe.$$
$$6\,KOH + FeC_2 = 2\,K + 2\,K_2CO_3 + 6\,H + Fe.$$

The fine iron is produced by passing hot carbonic oxide and hydrogen (water gas) over oxide of iron, commercially known as purple

ore, heated to 500° C. This fine iron is mixed with melted coal tar pitch in proper proportion, the mixture cooled, broken into lumps, and coked in iron retorts. This metallic coke consists of carbon and iron, in proportion similar to an iron carbide, from which the carbon or iron can not be separated by mechanical means. This is very finely ground. The vessels in which the caustic soda and iron carbide are heated are of cast steel, egg-shaped, 18 inches in their greatest diameters, and 3 feet high. They are made in two portions, the lower one in the form of a crucible, and the upper one, secured immovably in the upper part of the furnace, is provided with an upright stem and a hollow protruding arm; attached to the hollow arm is the condenser, which is 5 inches in diameter and 3 feet long, with a hole in the bottom, 20 inches from the nozzle. The bottom of the condenser is so inclined that the metal condensed from the vapor issuing from the crucible, during reduction, flows down and out of the small hole into a small iron pot placed beneath. The condensers at the outer end have a small hinged door, by means of which the workmen may observe the progress of the distillation. The stationary cover has a convex edge, which fits into a groove around the edge of the crucible. A little powdered lime makes the joint tight. The crucible, after receiving its charge of 50 pounds of caustic soda with the proper addition of iron carbide, is elevated by an hydraulic lift into the furnace and against the edge of the cover. The platform of the lift completely fills the aperture in the bottom of the furnace. The temperature of reduction and distillation is about 1,000° C. The furnace is heated by gas from a gas producer, which is burnt by air previously brought to a high temperature. The time of distillation is 70 minutes. The product is 6 pounds of sodium.

Upon the completion of the distillation the small pots containing the sodium are removed, and, when cool enough, the sodium is covered with high-test petroleum. It is then carried to the casting shop where it is melted under oil in large iron pots, heated by an oil bath, and cast in bars or in sticks.

The crucible is lowered, taken by a large pair of tongs, on wheels, to a dumping pit, the residue cleaned out, a new charge is placed in it, and it is then elevated again into the furnace. There are five crucibles in each furnace, and 7 minutes are required to draw, empty, recharge, and replace them. The works have four furnaces which can produce, altogether, over a ton of sodium in 24 hours.

The average duration of a crucible is one hundred and twenty charges. The residue from the distillation is treated with water to extract the carbonate of soda and the iron is used again to make the iron carbide.

The residue contains—

	Per cent.
Carbonate of soda	77
Peroxide of sodium	2
Carbon	2
Iron	19
	100

To produce sodium, a little more carbide is used than the reaction requires, and to produce potassium, a little less. The gas coming off in the first part of the distillation is pure hydrogen, and when the operation is nearly completed it contains 5 per cent. of carbonic oxide. In making potassium, owing to the smaller quantity of iron carbide, no carbonic oxide is formed, and therefore there is none of the black compound formed, as mentioned in the first part of this article.

Cost.—The following table of cost, as well as a portion of what goes before, was given in 1887 by James Mactear, in a lecture before the Society of Chemical Industry. It is based upon the results at the old works. The foregoing description relates to the new works, in which the cost is probably reduced:

	£	s.	d.
720 pounds caustic soda, £11 per ton	3	10	10
150 pounds carbide, ¼*d.* per pound		6	4
Labor	1	0	0
Fuel		17	0
Reconverting 624 pounds carbonate into caustic soda	1	0	0
	6	14	2
Deduct value of 475 pounds caustic soda	2	6	8
Cost of 120 pounds sodium	4	7	6
Equal per pound			8½
Wear and tear of crucible			1
Wear and tear of furnace			1
			10½

This is less than one-fourth the cost by the old process. The cheapness of production by the Castner process is due to the lower heat at which the metal is produced, the quickness of the operation, the less wear and tear of apparatus, the nonclogging of the condensers, and the small waste of materials.

The manufacturing operations for potassium cost no more than for sodium, the higher cost of the caustic potash being the chief element of increased expenses.

The uses of sodium and potassium will doubtless multiply, with their cost so materially reduced. Both sodium and potassium are powerful reducing agents. Aluminium, magnesium, silicon, boron, manganese, and chromium can be isolated by the use of sodium.

Sodium amalgam has been used in the extraction of gold. Con-

siderable quantities are used in the manufacture of antipyrene. It is now sold at 2 shillings per pound.

I introduce here a lecture on aluminium, by Sir Henry Roscoe, M. P., D. C. L., LL.D., F. R. S., delivered at the Royal Institution, London, Friday, May 3, 1889. Professor Roscoe is one the directors of the Aluminium Company:

Chemists of many lands have contributed to our knowledge of the metal aluminium. Davy, in 1807, tried in vain to reduce alumina by means of the electric current. Oerstedt, the Dane, in 1824, pointed out that the metal could be obtained by treating the chloride with an alkali metal; this was accomplished in Germany by Wöhler in 1827, and more completely in 1845, whilst in 1854 Bunsen showed how the metal can be obtained by electrolysis. But it is to France, by the hands of Henri St. Claire Deville, in the same year, that the honor belongs of having first prepared aluminium in a state of purity, and of obtaining it on a scale which enabled its valuable properties to be recognized and made available; and the bar of "silver-white metal from clay," was one of the chemical wonders in the first Paris Exhibition of 1855. Now England and America step in, and I have this evening to relate the important changes which further investigation has effected in the metallurgy of aluminium. The process suggested by Oerstedt, carried out by Wöhler, and modified by Deville, remains in principle unchanged. The metal is prepared, as before, by a reduction of the double chloride of aluminium and sodium, by means of metallic sodium in presence of cryolite; and it is, therefore, not so much a description of a new reaction as of improvements of old ones of which I have to speak.

I may perhaps be allowed to remind my hearers that more than 33 years ago, Mr. Barlow, then secretary to the Institution, delivered a discourse, in the presence of Mr. Deville, on the properties and mode of preparation of aluminium, then a novelty. He stated that the metal was then sold at the rate of £3 per ounce, and the exhibition of a small ingot, cast in the laboratory by Mr. Deville, was considered remarkable. As indicating the progress since made, I may remark that the metal is now sold at 20 shillings per pound, and manufactured by the ton, by the Aluminium Company, at their works at Oldbury, near Birmingham. The improvements which have been made in this manufacture by the zeal and energy of Mr. Castner, an American metallurgist, are of so important a character that the process may properly be termed the Deville-Castner process.

The production of aluminium previous to 1887 probably did not exceed 10,000 pounds per annum, whilst the price at that time was very high. To attain even this production required that at least 100,000 pounds of double chloride, and 40,000 pounds of sodium should be manufactured annually. From these figures an idea of the magnitude of the undertaking assumed by the Aluminium Company may be estimated, when we learn that they erected works having an annual producing capacity of 100,000 pounds of aluminium. To accomplish this required not only that at least 400,000 pounds of sodium, 800,000 pounds of chlorine, and 1,000,000 pounds of double chloride should be annually manufactured, but in addition that each of these materials should be produced at a very low cost, in order to enable the metal to be sold at 20 shillings per pound.

The works now cover a space of nearly 5 acres. They are divided into five separate departments, viz, (1) sodium, (2) chlorine, (3) chloride, (4) aluminium, and (5) foundry, rolling, wire mills, etc.

In each department an accurate account is kept of the production each day, the amount of material used, the different furnaces and apparatus in operation, etc. In this manner it has been found possible to ascertain each day exactly how the different processes are progressing and what effect any modification has either on cost, quantity, or quality of product. By this means a complicated chemical process

is reduced to a series of very simple operations, so that whilst the processes are apparently complicated and difficult to carry out successfully, this is not the case now that the details connected with the manufacture have been perfected and each operation carried on quite independently until the final materials are brought together for the production of the aluminium.

MANUFACTURE OF SODIUM.

The first improvement occurs in the manufacture of sodium by what is known as the "Castner process." The successful working of this process marks an era in the production of sodium, as it not only has greatly cheapened the metal, but has enabled the manufacture to be carried out on a very large scale with little or no danger. Practically, the process consists in heating fused caustic soda in contact with carbon whilst the former substance is in a perfectly liquid condition. By the process in vogue before the introduction of this method it was always deemed necessary that special means should be taken to guard against actual fusion of the mixed charges, which, if it were to take place, would to a large extent allow the alkali and reducing material to separate. Thus, having an infusible charge to heat, requiring the employment of a very high temperature for its decomposition, the iron vessels must be of small circumference to allow the penetration of the heat to the center of the charge without actually melting the vessel in which the materials are heated. By the new process, owing to the alkali being in a fused or perfectly liquid condition in contact directly with carbon, the necessity of this is avoided, and consequently the reduction can be carried on in large vessels at a comparatively low temperature. The reaction taking place may be expressed as follows:

$$3NaHO+C=Na2CO_3+3H+Na$$

The vessels in which the charges of alkali and reducing material are heated are of egg-shaped pattern, about 18 inches in width at their widest part and about 3 feet high, and are made in two portions, the lower one being actually in the form of a crucible, while the upper one is provided with an upright stem and a protruding hollow arm. This part of the apparatus is known as the cover. In commencing the operation these covers are raised in the heated furnace through apertures provided in the floor of the heated chamber and are then fastened in their place by an attachment adjusted to the stem; the hollow arm extends outside the furnace. Directly below each aperture in the bottom of the furnace are situated the hydraulic lifts, attached to the top of which are the platforms upon which are placed the crucibles to be raised into the furnace. Attached to the hydraulic lifts are the usual reversing valves for lowering or raising, and the platform is of such a size as when raised completely to fill the bottom aperture of the furnace. The charged crucible, being placed upon the platform, is raised into its position, the edges meeting those of the cover, forming an air-tight joint which prevents the escape of gas and vapor from the vessel during reduction, except by the hollow arm provided for this purpose. The natural expansion of the iron vessels is accommodated by the water-pressure in the hydraulic lifts, so that the joint of the cover and crucible is not disturbed until it is intended to lower the lift for the purpose of removing the crucible.

The length of time required for the first operation of reduction and distillation is about two hours. At the end of this time the crucibles are lowered, taken from the platforms by a large pair of tongs on wheels, carried to a dumping pit, and thrown on their sides. The residue is cleaned out, and the hot pot being again gripped by the tongs is taken back to the furnace. On its way the charge of alkali and reducing material is thrown in. It is again placed on the lift and raised in position against the edges of the cover. The time consumed in making the change

is one and one-half minutes, and it only requires about seven minutes to draw, empty, recharge, and replace the five crucibles in each furnace. In this manner the crucibles retain the greater amount of their heat, so that the operation of reduction and distillation now only requires one hour and ten minutes. Each of the four furnaces, of five crucibles each, when in operation are drawn alternately, so that the process is carried on night and day.

Attached to the protruding hollow arm from the cover are the condensers, which are of a peculiar pattern, specially adapted to this process, being quite different from those formerly used. They are about 5 inches in diameter and nearly 3 feet long, and have a small opening in the bottom about 20 inches from the nozzle. The bottom of these condensers is so inclined that the metal, condensed from the vapor issuing from the crucible during reduction, flows down and out into a small pot placed directly below this opening. The uncondensed gases escape from the condenser at the farther end and burn with the characteristic sodium flame. The condensers are also provided with a small hinged door at the farther end, by means of which the workmen from time to time may look in to observe how the distillation is progressing. Previous to drawing the crucibles from the furnace for the purpose of emptying and recharging, the small pots, each containing the distilled metal, are removed and empty ones substituted. Those removed each contain on an average about 6 pounds of metal, and are taken directly to the sodium casting shop, where it is melted and cast either into large bars ready to be used for making aluminium or in smaller sticks to be sold.

Special care is taken to keep the temperature of the furnaces at about 1,000° C., and the gas and air valves are carefully regulated, so as to maintain as even a temperature as possible. The covers remain in the furnace from Sunday night to Saturday afternoon, and the crucibles are kept in use until they are worn out, when new ones are substituted without interrupting the general running of the furnace. A furnace in operation requires 250 pounds of caustic soda every one hour and ten minutes, and yields in the same time 30 pounds of sodium and about 240 pounds of crude carbonate of soda. With the four furnaces at work 120 pounds of sodium can be made every seventy minutes, or over a ton in the twenty-four hours. The residual carbonate, on treatment with lime in the usual manner, yields two-thirds of the original amount of caustic operated upon. The sodium, after being cast, is saturated with kerosene oil, and stored in large tanks holding several tons, placed in rooms specially designed both for security against either fire or water.

CHLORINE MANUFACTURE.

This part of the works is connected with the adjacent works of Messrs. Chance Brothers by a large gutta-percha pipe, by means of which from time to time hydrochloric acid is supplied direct into the large storage cisterns, from which it is used as desired for making the chlorine. For the preparation of the chlorine gas needed in making the chloride, the usual method is employed; that is, hydrochloric acid and manganese dioxide are heated together, when chlorine gas is evolved with effervescence, and is led away by earthenware and lead pipes to large lead-lined gasometers, where it is stored.

The materials for the generation of the chlorine are brought together in large tanks, or stills, built up out of great sandstone slabs, having rubber joints, and the heating is effected by the injection of steam. The evolution of gas, at first rapid, becomes gradually slower, and at last stops; the hydrochloric acid and manganese dioxide being converted into chlorine and manganous chloride. This last compound remains dissolved in the "spent still liquor" and is reconverted into manganese dioxide, to be used over again, by Weldon's manganese recovery process. Owing to the difficulty of keeping up a regular supply of chlorine under a constant pressure directly from the stills, in order that the quantity passed into the sixty different

retorts in which the double chloride is made can be regulated and fed as desired, four large gasometers were erected. Each of these is capable of holding 1,000 cubic feet of gas, and is completely lined with lead, as are all the connecting mains, etc., this being the only available metal which withstands the corrosive action of chlorine. The gasometers are filled in turn from the stills, the chlorine consumed being taken direct from the gasometer under a regular pressure until it is exhausted, the valves being changed, the supply is taken from another holder, the emptied one being refilled from the still.

MANUFACTURE OF THE DOUBLE CHLORIDE.

Twelve large regenerative gas furnaces are used for heating, and in each of these are fixed five horizontal fire-clay retorts about 10 feet in length, into which the mixture for making the double chloride is placed. These furnaces have been built in two rows, six on a side, the clear passage way down the center of the building, which is about 250 feet long, being 50 feet in width. Above this central passage is the staging, carrying the large lead mains for the supply of the chlorine coming from the gasometers. Opposite each retort and attached to the main, are situated the regulating valves, connected with lead and earthenware pipes, for the regulation and passage of the chlorine to each retort. The valves are of peculiar design, and have been so constructed that the chlorine is made to pass through a certain depth of liquid, which not only by opposing a certain pressure allows a known quantity of gas to pass in a given time, but also prevents any return from the retort into the main, should an increase of pressure be suddenly developed in the retorts.

The mixture with which the retorts are charged is made by grinding together hydrate of alumina, salt, and charcoal. This mixture is then moistened with water, which partially dissolves the salt, and thrown into a pug mill of the usual type for making drain pipes, excepting that the mass is forced out into solid cylindrical lengths upon a platform alongside of which a workman is stationed with a large knife, by means of which the material is cut into lengths of about 3 inches each. These are then piled on top of the large furnaces to dry. In a few hours they have sufficiently hardened to allow of their being handled. They are then transferred to large wagons, and are ready to be used in charging the retorts.

The success of this process is in a great measure dependent, first, on the proportionate mixture of materials; second, on the temperature of the furnace; third, on the quantity of chlorine introduced in a given time; and fourth, on the actual construction of the retorts. I am, however, not at liberty to discuss the details of this part of the process, which have only a commercial interest. In carrying on the operation, the furnaces or retorts, when at the proper temperature, are charged by throwing in the balls until they are quite full, the fronts are then sealed up, and the charge allowed to remain undisturbed for about four hours, during which time the water of the alumina hydrate is completely expelled. At the end of this time the valves on the chlorine main are opened, and the gas is allowed to pass into the charged retorts. In the rear of each retort, and connected therewith by means of an earthenware pipe, are the condenser boxes, which are built in brick. These boxes are provided with openings or doors, and also with earthenware pipes, connected with a small flue for carrying off the uncondensed vapors to the large chimney. At first the chlorine passed into each retort is all absorbed by the charge, and only carbonic oxide escapes into the open boxes, where it burns. After a certain time, however, dense fumes are evolved, and the boxes are then closed, while the connecting pipe between the box and the small flue serves to carry off the uncondensed vapors to the chimney.

The reaction which takes place is as follows:

$$Al_2O_3 + 2NaCl + 3C + 6Cl = 2AlCl_3NaCl + 3CO.$$

The chlorine is passed in for about 72 hours in varying quantity, the boxes at the back being opened from time to time by the workmen to ascertain the progress of the distillation. At the end of the time mentioned the chlorine valves are closed and the boxes at the back of the furnace are all thrown open. The crude double chloride as distilled from the retorts, condenses in the connecting pipe and trickles down into the boxes, where it solidifies in large irregular masses. The yield from a bench of five retorts will average from 1,600 to 1,800 pounds, which is not far from the theoretical quantity. After the removal of the crude chloride from the condenser boxes the retorts are opened at their charging end, and the residue, which consists of a small quantity of alumina, charcoal, and salt is raked out and remixed in certain proportions with fresh material to be used over again. The furnace is immediately recharged and the same operations repeated, so that from each furnace upward of 3,550 pounds of chloride are obtained weekly. With ten of the twelve furnaces always at work the plant is easily capable of producing 30,000 pounds of chloride per week, or 1,500,000 pounds per annum.

Owing to the presence of iron, both in the materials used (viz, charcoal, alumina, etc.) and in the fire clay composing the retorts, the distilled chloride always contains a varying proportion of this metal in the form of ferrous and ferric chlorides. When it is remembered that it requires 10 pounds of this chloride to produce 1 pound of aluminium by reduction, it will be quite apparent how materially a very small percentage of iron in the chloride will influence the quality of the resulting metal. I may say that, exercising the utmost care as to the purity of the alumina and the charcoal used, and after having the retorts made of special fire clay containing only a very small percentage of iron, it was found almost impossible to produce upon a large scale a chloride containing less than 0.3 per cent. of iron.

This crude double chloride, as it is now called at the works, is highly deliquescent, and varies in color from a light yellow to a dark red. The variation in color is not so much due to the varying percentage of iron contained as to the relative proportion of ferric or ferrous chlorides present, and although a sample may be either very dark or quite light, it may still contain only a small percentage of iron if it be present as ferric salt, or a very large percentage if it is in the ferrous condition. Even when exercising all possible precautions, the average analysis of the crude double chloride shows about 0.4 per cent. of iron. The metal subsequently made from this chloride therefore never contained much less than about 5 per cent. of iron, and, as this quantity greatly injures the capacity of aluminium for drawing into wire, rolling, etc., the metal thus obtained required to be refined. This was successfully accomplished by Mr. Castner and his able assistant Mr. Cullen, and for some time all the metal made was refined, the iron being lowered to about 2 per cent.

The process, however, was difficult to carry out, and required careful manipulation, but as it then seemed the only remedy for effectively removing the iron, it was adopted and carried on for some time quite successfully, until another invention of Mr. Castner rendered it totally unnecessary. This consisted in purifying the double chloride before reduction. I can not now explain this process, but I am able to show some of the product.* This purified chloride, or pure double chloride, is, as you see, quite white, and is far less deliquescent than the crude, so that it is quite reasonable to infer that this most undesirable property is greatly due to the former presence of iron chlorides. I have seen large quantities containing upward of 1½

* By the reduction of the iron salts to metallic iron by melting the chloride (single or double) with a quantity of aluminium or sodium sufficient for this purpose.—United States patent.

per cent. of iron, or 150 pounds to 10,000 of the chloride, completely purified from iron in a few minutes, so that, whilst the substance before treatment was wholly unfit for the preparation of aluminium, owing to the presence of iron, the result was, like the sample exhibited, a mass containing only 1 pound of iron in 10,000, or 0.01 per cent. The process is extremely simple, and adds little or no appreciable cost to the final product. After treatment, this pure chloride is melted in large iron pots and run into drums similar to those used for storing caustic soda. As far as I am aware, it was generally believed to be an impossibility to remove the iron from anhydrous double chloride of aluminium and sodium, and few if any chemists have ever seen a pure white double chloride.

ALUMINIUM MANUFACTURE.

I now come to the final stage of the process, viz, the reduction of the pure double chloride by sodium. This is effected, not in a tube of Bohemian glass, as shown in Mr. Barlow's lecture in 1856, but in a large reverberatory furnace, having an inclined hearth about 6 feet square, the inclination being toward the front of the furnace, through which are several openings at different heights. The pure chloride is ground together with cryolite in about the proportions of two to one, and is then carried to a staging erected above the reducing furnace. The sodium, in large slabs or blocks, is run through a machine similar to an ordinary tobacco-cutting machine, where it is cut into small thin slices; it is then also transferred to the staging above the reducing furnace.

Both materials are now thrown into a large revolving drum, when they become thoroughly mixed. The drum being opened and partially turned, the contents drop out into a car on a tramway directly below. The furnace having been raised to the desired temperature, the dampers of the furnace are all closed to prevent the access of air, the heating gas being also shut off. The car is then moved out on the roof of the furnace until it stands directly over the center of the hearth. The furnace roof is provided with large hoppers, and through these openings the charge is introduced as quickly as possible. The reaction takes place almost immediately, and the whole charge quickly liquefies. At the end of a certain time the heating gas is again introduced and the charge kept at a moderate temperature for about two hours. At the end of this period the furnace is tapped by driving a bar through the lower opening, which has previously been stopped with a fire-clay plug, and the liquid metal run out in a silver stream into molds placed below the opening. When the metal has all been drawn off, the slag is allowed to run out into small iron wagons and removed. The openings being again plugged up, the furnace is ready for another charge. From each charge, composed of about 1,200 pounds of pure chloride, 600 pounds of cryolite, and 350 pounds of sodium, about 115 to 120 pounds of aluminium are obtained.

$$AlCl_3NaCl + 3Na = Al + 4NaCl.$$

The purity of the metal entirely depends upon the purity of the chloride used, and without exercising more than ordinary care the metal tests usually indicate a purity of metal above 99 per cent. On the table is the metal run from a single charge, its weight is 116 pounds, and its composition, as shown by analysis, is 99.2 aluminium, 0.3 silicon, and 0.5 iron. This I believe to be the largest and the purest mass of metal ever made in one operation.

The result of eight or nine charges are laid on one side, and then melted down in the furnace to make a uniform quality, the liquid metal, after a good stirring, being drawn off into molds. These large ingots, weighing about 60 pounds each, are sent to the casting shop, there to be melted and cast into the ordinary pigs or other shapes, as may be required for the making of tubes, sheets, or wire, or else used directly for making alloys of either copper or iron.

The following table shows approximately the quantity of each material used in the production of 1 ton of aluminium:

Metallic sodium	pounds	6,300
Double chloride	do	22,400
Cryolite	do	8,000
Coal	tons	8

To produce 6,300 pounds of sodium is required:

Caustic soda	pounds	44,000
Carbide made from pitch, 12,000 pounds, and iron turnings, 1,000 pounds	pounds	7,000
Crucible castings	tons	2½
Coal	do	75

For the production of 22,400 pounds double chloride is required;

Common salt	pounds	8,000
Alumina hydrate	do	11,000
Chlorine gas	do	15,000
Coal	tons	180

For the production of 15,000 pounds of chlorine gas is required:

Hydrochloric acid	pounds	180,000
Limestone dust	do	45,000
Lime	do	30,000
Loss of manganese	do	1,000

It might seem, on looking over the above numbers, as if an extraordinary amount of waste occurred, and as if the production is far below that which ought to be obtained, but a study of the figures will show that this is not the case.* I would wish to call attention to one item in particular, viz, fuel, it having been remarked that the consumption of coal must prevent cheap production. I think when it is remembered that coal, such as used at the works, cost only 4*s.* per ton, while the product is worth £2,240 per ton, the cost of coal is not an item of consequence in the cost of production. The total cost of the coal to produce 1 ton of metal being £50, the actual cost for fuel is less than 6*d.* for every pound of aluminium produced. The ratio of cost of fuel to value of product is indeed less than is the case in making either iron or steel. In concluding my remarks as to the method of manufacture and the process in general, I may add that I do not think it is too much to expect, in view of the rapid strides already made, that in the future, further improvements and modifications will enable aluminium to be produced and sold even at a lower price than appears at present possible.

PROPERTIES OF ALUMINIUM.

In its physical properties aluminium widely differs from all the other metals. Its color is a beautiful white with a slight blue tint. The intensity of this color becomes more apparent when the metal has been worked, or when it contains silicon or iron. The surface may be made to take a very high polish, when the blue tint of the metal become manifest, or it may be treated with caustic soda and then nitric acid, which will leave the metal quite white. The extensibility or malleability of aluminium is very high, ranking with gold and silver if the metal be of good quality. It may be beaten out into thin leaf quite as easily as either gold or silver, although it requires more careful annealing.

*These works can produce 500 pounds of aluminium per day. The metal run out represents 70 per cent. of the aluminium in the charge and 80 per cent. of the weight which the sodium put in should reduce.—Richards.

It is extremely ductile and may be easily drawn, especial care only being required in the annealing.

The sonorousness of aluminium is very great. Faraday has remarked, after experiments conducted in his laboratory, that the sound produced by an ingot of aluminium is not simple, and one may distinguish two sounds by turning the vibrating ingot.

After being cast it has about the hardness of pure silver, but may be sensibly hardened by hammering.

Its tensile strength varies between 12 and 14 tons to the inch (test sample which was shown having been broken at 13 tons or 27,000 pounds), ordinary cast-iron being about 8 tons. Comparing the strength of aluminium in relation to its weight, it is equal to steel of 38 tons tensile strength. The specific gravity of cast aluminium is 2.58, but after rolling or hammering this figure is increased to about 2.68.

The specific gravity of aluminium being 1, copper is 3.6, nickel 3.5, silver 4, lead 4.8, gold 7.7.

The fusibility of aluminium has been variously stated as being between that of zinc and silver, or between 600° and 1,000° C.

As no reliable information has ever been made public on this subject, my friend, Professor Carnelley, undertook to determine it. I was aware, from information gained at the works at Oldbury, that a small increase in the percentage of contained iron materially raised its point of fusion, and it has been undoubtedly due to this cause that such wide limits are given for the melting point. Under these circumstances two samples were forwarded for testing, of which No. 1 containing 0.5 per cent. of iron, had a melting point of 700° C.; whereas No. 2, containing 5 per cent. of iron, does not melt at 700° and only softens somewhat above that temperature but undergoes incipient fusion at 730°.

According to Faraday, aluminium ranks very high among metallic conductors of heat and electricity, and he found that it conducted heat better than either silver or copper. The specific heat is also very high, which accounts for length of time required for an ingot of the metal to either melt or get cold after being cast.

Chemically, its properties are well worthy of study.

Air, either wet or dry, has absolutely no effect on aluminium at the ordinary temperature, but this property is only possessed by a very pure quality of metal, and the pure metal in mass undergoes only slight oxidation even at the melting point of platinum.

Thin leaf, however, when heated in a current of oxygen, burns with a brilliant bluish white light. If the metal be pure, water has no effect on it whatever, even at a red heat. Sulphur and its compounds also are without action on it, while, under the same circumstances, nearly all metals would be discolored with great rapidity.

Dilute sulphuric acid and nitric acid, both diluted and concentrated, have no effect on it, although it may be dissolved in either hydrochloric acid or caustic alkali. Heated in an atmosphere of chlorine it burns with a vivid light, producing aluminium chloride. In connection with the subject it may be of interest to state the true melting point of the double chloride of aluminium and sodium, which has always been given at 170° to 180° C., but which Mr. Baker, the chemist to the works, finds lies between 125° and 130° C.

USES OF ALUMINIUM.

Its uses, unalloyed, have heretofore been greatly restricted. This is, I believe, alone owing to its former high price, for no metal possessing the properties of aluminium could help coming into larger use if its cost were moderate. Much has been said as to the impossibility of soldering it being against its popular use, but I believe that this difficulty will soon be overcome. The following are a few of the purposes

to which it is at present put: telescope tubes, marine glasses, eyeglasses and sextants, especially on account of its lightness. Fine wire for the making of lace, embroidery, etc. Leaf in the place of silver leaf, sabre sheaths, sword handles, etc., statuettes and works of art, jewelry and delicate physical apparatus, culinary utensils, harness fittings, metallic parts of soldiers' uniforms, dental purposes surgical instruments, reflectors (it not being tarnished by the products of combustion), photographic apparatus, aëronautical and engineering purposes, and especially for the making of alloys.

ALLOYS OF ALUMINIUM.

The most important alloys of aluminium are those made with copper. These alloys were first prepared by Dr. Percy, in England, and now give promise of being largely used. The alloy produced by the addition of 10 per cent. of aluminium to copper, the maximum amount that can be used to produce a satisfactory alloy, is known as aluminium bronze. Bronzes, however, are made which contain smaller amounts of aluminium, possessing in a degree the valuable properties of the 10 per cent. bronze. According to the percentage of aluminium up to 10 per cent., the color varies from red gold to pale yellow. The 10 per cent. alloy takes a fine polish, and has the color of jewelers' gold. The 5 per cent. alloy is not quite so hard, the color being very similar to that of pure gold. I am indebted to Prof. Roberts Austen for a splendid specimen of crystallized gold, as also for a mold in which the gold at the mint is usually cast, and in this I have had prepared ingots of the 10 and 5 per cent. alloy, so that a comparison may be made of the color of these with a gold ingot cast in the same mold, for the loan of which I have to thank Messrs. Johnson, Matthey & Co., all of which are before you.

I have also ingots of the same size, of pure aluminium, from which an idea of the relative weights of gold and aluminium may be obtained.

To arrive at perfection in the making of these alloys, not only is it required that the aluminium used should be of good quality, but also that the copper must be of the very best obtainable. For this purpose only the best brands of Lake Superior copper should be used. Inferior brands of copper or any impurities in the alloy give poor results. The alloys all possess a good color, polish well, keep their color far better than all other copper alloys, are extremely malleable and ductile, can be worked either hot or cold, easily engraved, the higher grades have an elasticity exceeding steel, are easily cast into complicated objects, do not lose in remelting, and are possessed of great strength, dependent, of course, on the purity and percentage of contained aluminium. The 10 per cent. alloy, when cast, has a tensile strength of between 70,000 and 80,000 pounds per square inch, but when hammered or worked, the test exceeds 100,000 pounds. (A sample shown broke at 105,000 pounds.)

An attempt to enumerate either the present uses or the possible future commercial value of these alloys is beyond my present purpose. I may, however, remark that they are not only adapted to take the place of bronze, brass, and steel, but they so far surpass all of those metals, both physically and chemically, as to make their extended use assured. (Sheets, rods, tubes, wire, and ingots shown.)

But even a more important use of aluminium seems to be its employment in the iron industry, of which it promises shortly to become a valuable factor, owing to certain effects which it produces when present, even in the most minute proportions. Experiments are now being carried on at numerous iron and steel works, in England, on the continent, and in America. The results so far obtained are greatly at variance, for whilst in the majority of cases the improvements made have encouraged the continuance of the trials, in others the result has not been satisfactory. On this point I would wish to say to those who may contemplate making use of aluminium in this direction, that it would be advisable before trying their experiments to ascer-

tain whether the aluminium alloy they may purchase actually contains any aluminium at all, for some of the so-called aluminium alloys contain little or no aluminium, and this may doubtless account for the negative results obtained. Again, others contain such varying proportions of carbon, silicon, and other impurities as to render their use highly objectionable.

It seems to be a prevailing idea with some people, that because aluminium is so light compared with iron, that they can not be directly alloyed, and furthermore, that for the same reason, alloys made by the direct melting together of the two metals would not be equal to an alloy where both metals are reduced together. Now, of course, this is not the case, and the statement has been put forward by those who were only able to make the alloys in one way.

Aluminium added to molten iron and steel lowers their melting points, consequently increases the fluidity of the metal, and causes it to run easily into molds and set there, without entrapping air and other gases, which serve to form blow holes and similar imperfections. It is already used by a large number of steel founders, and seems to render the production of sound steel castings more certain and easy than is otherwise possible.

One of the most remarkable applications of this property which aluminium possesses of lowering the melting-point of iron has been made use of by Mr. Nordenfelt in the production of castings of wrought iron.

Aluminium forms alloys with most other metals, and although each possess peculiar properties which in the future may be utilized, at present they are but little used.

In conclusion, I beg to call your attention to the wood models on the table, one being representative of aluminium, the other aluminium bronze. The originals of these models are now in the Paris Exhibition, each weighing 1,000 pounds. With regard to aluminium bronze, I can not speak positively, but the block of pure aluminium is undoubtedly the largest casting ever made in this most wonderful metal. I have to thank the directors of the Aluminium Company, and especially Mr. Castner, for furnishing me with the interesting series of specimens of raw and manufactured metal for illustrating my discourse.

NOTE.—The exhibit consisted of 5 to 6 cwt. of aluminium (98 to 99 per cent.) in various sizes of pigs, ingots, sheet, wire, foil, tubes, and rods; two large blocks, together weighing 116 pounds, and testing 99.2 per cent. aluminium, as run direct from the furnace in one charge; 4 cwt. of aluminium bronzes in pigs, ingots, wire, tubes, sheet, and rods; aluminium iron and steel, 10 and 20 per cent. aluminium, 1 cwt. of each in pigs; sodium in cast bars; double chloride of aluminium and sodium (crude and purified).

The following is extracted from a pamphlet published by this company:

PROPERTIES.

The properties here mentioned only relate to the metal (as manufactured by this company) containing 97 to 98 per cent. of aluminium, which possesses a luster closely approaching silver, and has a specific gravity of about one-third of that of iron. It is almost as malleable as silver, with which metal it compares favorably in regard to ductility, elasticity, tenacity and hardness. Its melting point is between that of silver and copper, and while it conducts heat better than the former, it ranks next to the latter as a conductor of electricity. It is not acted upon by sulphurous gases, nor by air at ordinary temperatures, which would, under like circumstances, greatly discolor silver; and while it dissolves freely in hydrochloric acid and strong caustic alkalis, it withstands the action of nitric, sulphuric and organic acids to a considerable degree.

MANIPULATIONS IN WORKING.

Melting is best performed in an ordinary plumbago crucible, although an earthen crucible will answer.

No flux should be used, and only part of a charge must be melted at a time, adding little by little, and so increasing the charge as the mass becomes melted. The pieces which are to be melted should be dipped in benzine previous to being put in the crucible. As the melted aluminium reduces the silica of the crucible to silicon, forming an alloy, and therefore becoming impure, the fewer times the metal is melted the less liable it is to become contaminated.

Casting can easily be accomplished either in metallic molds, or, preferably, in sand for complicated objects. Care should be taken that the mold be dry, and so constructed as to freely allow the escape of air replaced by viscous metal. The mold should be provided with many vents, and should also have a perfectly round git. The melted metal must be quickly poured, allowing enough, however, to remain in the git to provide for the contraction upon solidification. Covered iron ingot molds serve best for casting bars which are intended to be rolled.

Rolling and drawing is accomplished as with other metals, but owing to its quickly losing its temper it requires to be more frequently annealed. The proper temper for annealing is a very low red heat. When drawing into wire, the diameter should be very gradually reduced with frequent heating, special care being taken regarding the temperature, owing to the fusibility of the metal.

Soldering is not easily accomplished, although the company hopes very shortly to place before their customers a perfect method, in the mean time special information will be supplied to those desiring it.

Burnishing.—The polishing stone is dipped into an emulsion made of equal parts of rum and olive oil, and the metal polished like silver, special care being taken not to press too hard in shining up. Hammered and pressed objects of aluminium before being polished, can be easily ground by using olive oil and pumice.

Matting, silvering, gilding, etc.—Aluminium takes a beautiful mat, which is quite easily obtained by plunging the object into a very dilute solution of caustic soda for an instant, washing well in water, and then dipping into strong nitric acid. The surface thus given will keep indefinitely in the air. Silvering, gilding, etc., of aluminium require special information, depending upon the results desired, which will be furnished on application to the company.

USES OF ALUMINIUM.

Heretofore the two points which have stood in the way of the extensive use of aluminium, in the many directions for which its varied valuable properties have fitted it, have been: First, its excessive cost; second, its impurity. That this company has overcome these obstacles is proved by its now offering for sale in any desired quantity, a metal guarantied to contain above 97 per cent. of aluminium, at the price of 20*s.* per pound. In comparing the price of aluminium with metals such as nickel, tin, or silver, it must be borne in mind that, for the same bulk, it is only about one-quarter the weight; so that, while an object made in aluminium weighing one pound would cost 20*s.*, a similar object made in either nickel, tin, or silver would weigh 4 pounds, and cost 9*s.*, 7*s.*, and 180*s.*, respectively. Thus, for the same bulk, it is only two and a quarter times the cost of nickel, three times the cost of tin, and one-ninth the cost of silver. The principal use of aluminium at present is in the production of alloys, and for this purpose it is most eminently adapted; small percentages increase the strength of and render far more unoxidizable the metals and alloys to which it is added. The following are but a few of the numberless uses to which it has been put at various times, and now that the different trades are assured of a constant supply at a reasonable price, nothing can

prevent its rapidly entering into everyday uses: Telescope tubes, opera glasses, sextants, physical and surgical apparatus, statuettes and works of art, culinary utensils, coinage, leaf in place of gold and silver, jewelry, ballooning purposes, and in place of any metal now used where lightness and resistance to oxidation are advantages.

ALUMINIUM SILVER, IN PIGS, INGOTS, SHEETS, RODS, AND WIRE.

Aluminium	93½ to 95
Silver	4½ to 5

Properties.—This alloy possesses in a degree the properties of pure aluminium, excepting that it is much harder, takes a fine polish, does not oxidize under ordinary conditions, and has nearly the color of pure silver.

Manipulation in working.—The same directions given with reference to pure aluminium apply to this alloy.

Uses.—For any purpose in place of silver, or in place of pure aluminium where a harder metal is required, combining lightness with the hardness.

ALUMINIUM BRONZES, IN PIGS, INGOTS, SHEETS, RODS, AND WIRE.

[Analysis guarantied.]

Grade.	Copper.	Aluminium.
	Per cent.	*Per cent.*
A	89 to 90	9½ to 10
B	92½ 93	7 7½
C	94½ 95	4½ 5
D	97 97½	2 2½

SCIENTIFIC EXTRACTS REGARDING THE PROPERTIES, MANIPULATIONS, AND USES OF THESE BRONZES.

From Deville.—"The aluminium and copper alloys with 2 or 3 per cent. of aluminium are used by Mr. Christofle for large castings of objects of art. They are harder than aluminium, and work well under the burin and chisel."

"The alloy with 10 per cent. of aluminium had its useful properties first described by Mr. Debray. It is very hard, can be beaten when cold, but with remarkable perfection when hot, and may well be compared to iron, which it resembles in all these physical properties; it is also very ductile.

"The 10 per cent. aluminium alloy is usually known as aluminium bronze. It behaves as a true alloy, and in consequence will not liquate into different combinations. This is proven by the fact that, when in making the alloy, the *pure copper* is in the crucible, and a bar of aluminium is added, the combination takes place with such disengagement of heat, that if the crucible is not of good quality it will be fused, for the whole attains a white heat. The color of the bronze is exactly that of 'green gold' (an alloy of gold and silver), and it receives a beautiful polish, being comparable in this regard only to steel. Its chemical properties do not differ much from those of most of the alloys of copper. However, in numerous experiments, it has been found to resist most chemical agents much better than these, especially sea water and sulphureted hydrogen. Its tenacity is equal to steel. According to experiments as to its wear in the form of journal boxes, it is found to wear away less than any other journal metal yet tried. Its malleability is almost perfect, as is seen by the following report of Mr. Boudaret, a practical engineer: 'First, aluminium bronze is malleable at all temperatures, from bright red to cold; sec-

ond, it is perfectly malleable at a red heat, breaking less and elongating more than pure copper; third, it is hard to roll in the cold, after several passes it ceases to elongate, and must then be annealed very often, or it will break quickly; fourth it results from the foregoing that it is best to roll it at as great a heat as possible below fusion; annealing and tempering render it softer than simple annealing. If after being annealed at a bright red heat it is let cool in still air to redness and then plunged in cold water it is ductile and malleable enough in the cold to stand all industrial working.'"

From Tessier Brothers.—"Just as copper increases the hardness of aluminium, so aluminium in small proportions increases the hardness of copper; however, aluminium does not injure its malleability, but makes it susceptible of taking a beautiful polish, and, according to the proportions, varies its color from red gold to pale yellow.

"These facts were announced some time back by Dr. Percy, in England. We have made large quantities of these alloys, and we may say that they leave nothing to be desired in luster or color to make them perfect imitations of gold. They alter much less by successive fusions than the alloys of copper with tin and zinc employed for the same purpose. A 10 per cent. aluminium alloy was harder than our gold coin, took a fine polish by burnishing, and had the color of pale jewelers' gold; it could be forged and worked the same as copper. The 5 per cent aluminium alloy was less hard than the preceding, but, like it, takes a fine polish, and in tint approaches nearly to pure gold. Alloys with 5 per cent. to 10 per cent. of aluminium may have their color changed at will, either by leaving in nitric acid, which takes away the copper and leaves the aluminium, or in hydrochloric, which takes away the aluminium, leaving the copper. The resistance, hardness, and elasticity which are communicated to copper by introducing small quantities of aluminium will certainly make these important industrial alloys."

From Mierzinski.—"Two points are to be attended to in making aluminium bronze. First: *A pure copper must be used.* The best is that electrically deposited, but it generally costs too much. The next best is the Lake Superior brand; the usual commercial copper gives all sorts of poor results, owing to the antimony, arsenic, tin, zinc, or iron contaminating it. The bronze loses by being alloyed with zinc or tin. Secondly, the alloy must be remelted two or three times to remove its brittleness.

"In all probability the percentage of aluminium increases by remelting. The usual alloys are those of 1, 2, 5, and 10 per cent. aluminium. The 5 per cent. bronze is golden in color, polishes well, and casts beautifully; is very malleable cold or hot, and has great strength, especially after hammering. The 7½ per cent. bronze is to be recommended as superior to the 5 per cent.; it has a peculiar greenish gold color, which makes it very suitable for decoration.

"All these good qualities are possessed by the 10 per cent. bronze. It is bright golden, keeps its polish in the air, may be easily engraved, shows an elasticity much greater than steel, and can be soldered with hard solder. It gives good castings of all sizes, and runs in sand molds very uniformly. Thin castings come out very sharp, but if a casting is thin and suddenly thickens, small offshoots must be made at the thick place into which the metal can run, and then soak back into the castings by shrinkage at the thick part. Its strength, when cast, is between that of iron and steel, but when hammered, is equal to the best steel. It may be forged at about the same heat as cast steel, and then hammered until it is almost cold without breaking or ripping. Tempering makes it soft and malleable. It does not foul a file, and may be easily drawn into wire. Any part of a machine which is usually made of steel can be replaced by this bronze.

"As a solder for it, Hulot uses an alloy of the usual half-and-half lead-tin solder with 12½, 25 or 50 per cent. of zinc 'amalgam.'"

From Roscoe & Schorlemmer's Chemistry.—"Copper forms an alloy with aluminium, possessing the color of gold. For the preparation of this alloy *chemically pure copper must be employed*, as that which contains iron yields an inferior product. When fused several times it becomes malleable, yet yields fine castings, takes a fine polish, and is equal to steel in tensile strength. As in the case of aluminium, great hopes were entertained of the employment of this alloy, as it is less alterable in air than even brass or bronze. Rifle barrels. and even rifle cannon have been made from it. These appear to answer admirably, but the high price of 6s. per pound has prevented its general employment."

From Thurston's Materials for Engineering.—"The 10 per cent. bronze has a tenacity of about 100,000 pounds, compressive strength 130,000 pounds, and its ductility and toughness are such that it does not even crack when distorted by this load. It is so ductile and malleable that it can be drawn down under a hammer to the fineness of a cambric needle. It works well, casts well, holds a fine surface under the tool, and, when exposed to the weather, it is in every respect the best bronze known. Its high cost has alone prevented its extensive use in the arts. The alloys are very uniform in character. Every 1 per cent. of aluminium added to copper causes a considerable increase in ductility, increases its fusibility, and enables it to cast well; 2 per cent. gives a mixture used for castings which are to be worked with a chisel. It is softened by sudden cooling from a red heat. Its coëfficient of expansion is small at ordinary temperatures. It has great elasticity when made into springs."

The users of aluminium bronze will find that the above described valuable properties are only possessed by bronzes which are practically free from iron, silicon, or carbon.

SUGGESTIONS TO BE OBSERVED IN CASTING ALUMINIUM BRONZE.

Melting point of aluminium bronze is about the same as gun metal; if anything, a little higher, the low per cent. alloy requiring the higher temperature.

Shrinkage is about 50 per cent. more than brass, and due allowance must be made for this in molding. Cores to be made on hay-bands, if large, and as yielding as can be at all times, and mold must be cut away on metal setting, to prevent breaking of casting, if the shape requires it.

Green sand cores may be used in some cases for small castings, or rosin in coarse sand, and plenty of cinders to make it yielding.

Risers and feeding heads must be larger than casting where fed, and not too short, so as to have plenty of metal fluid up to time of setting in the real casting. It can not well be pumped or fed with a rod, as in iron casting.

All gates, etc., to be as large as possible, as the metal should be poured quickly, and as cold as it will run, to avoid the excessive shrinkage.

Dry sand molds to be of a good open character, green sand for small castings may be finer.

Good venting in all cases.

The metal should be kept covered with charcoal, to guard against formation of oxide as much as possible, and in large castings, poured from a hole in bottom of ladle, opened or closed with a plug, as in steel casting. Smaller castings may have a basin to hold all the metal necessary, on top of mold and shut with a plug of iron; fill this from ladle, and when scum is risen draw the plug. Or a combination of these methods may be used, according to circumstances, the main object being to keep out the oxide by running from the bottom of metal.

If metal is run to bottom of mold first, and run cool, it might be found advisable to put some warmer metal on top of risers when they show, so they may remain fluid a little longer. The same ladle will suffice perhaps, as metal has not traversed the mold.

Iron molds, for wire strips, etc., black with mixture of plumbago, pipe clay, and lard oil, and pour quickly.

FERRO-ALUMINIUM (ALUMINIUM STEEL) IN PIGS AND INGOTS.

A grade (guarantied analysis):

	Per cent.
Aluminium	19½ to 20
Iron	79½ to 80

B grade (guarantied analysis):

	Per cent.
Aluminium	9½ to 10
Iron	89½ to 90

The following analyses from Joseph W. Richards' book on "Aluminium," Philadelphia, 1890, will show the amount of impurities present in commercial aluminium, and also, incidentally, the improvement which has been achieved since the beginning of the industry in 1854:

No.	Process.	Aluminium.	Silicon.	Iron.
1	Deville	88.350	2.87	2.40
2	....do	92.500	0.70	6.80
3	....do	92.000	0.45	7.55
4	....do	92.969	2.149	4.88
5	....do	94.700	3.70	1.60
6	....do	96.160	0.47	3.37
7	Tissier Brothers	94.800	4.40	0.80
8	Morin & Co., Nanterre	97.200	0.25	2.40
9	....do	97.000	2.70	0.30
10	....do	98.290	0.04	1.67
11	....do	97.680	0.12	2.20
12	Merle & Co., Salindres	96.253	0.454	3.293
13	...do	96.890	1.270	1.840
14	....do	97.400	1.00	1.30
15	....do	97.600	0.40	1.40
16	Frishmuth	97.490	1.90	0.61
17	....do	97.750	1.70	0.55
18	Hall	98.340	1.34	0.32
19	Deville-Castner	99.200	0.50	0.30
20	Grabau	99.620	0.23	0.15
21	....do	99.800	0.12	0.08

Notes on the above analyses—

1. Analyzed by Salvêtat. Contained also 6.38 per cent. of copper and à trace of lead.
2 and 6. Analyzed by Dumas.
3. Parisian aluminium bought in La Haag.
4. Analyzed by Salvêtat. Contained also a trace of sodium.
5. Parisian aluminium bought in Bonn and analyzed by Dr. Kraut.
7. Made at the works near Rouen, in 1858, from cryolite. Analyzed by Demondêur.
8. Analyzed by Sauerwein. Contained also traces of lead and sodium.
9. Analyzed by Morin. Average of several months' work.
10, 11. Analyzed by Kraut. Represents the best product of the French works sent to the London Exhibition in 1862.

2, 13. Analyzed by Mallet. The best metal which could be bought in 1880. Purchased in Berlin by Mallet and used by him as the material which he purified and used for determining the atomic weight of aluminium.

14, 15. Analyzed by Hampe. This was the purest metal which could be bought in 1876. No. 14 contained also 0.10 per cent. of copper and 0.20 per cent. of lead. No. 15 contained 0.40 per cent. of copper and 0.20 per cent. of lead.

16. Bought in Philadelphia as Frishmuth's aluminium, in 1885, and analyzed by the author.

17. Specimen of the metal composing the tip of the Washington Monument, cast by Frishmuth. This analysis is reported by R. L. Packard in the Mineral Resources of the United States, 1883–'84.

18. The best grade of metal made by this process, analyzed by Hunt & Clapp, Pittsburgh:

19. The best grade made by this process, exhibited at the Paris Exposition, 1889. Analyzed by Cullen.

20. Analysis by Dr. Kraut of metal being made on a commercial scale.

21. Analysis by Grabau of the purest metal yet obtained by his process.

According to Rammelsberg (Kerl's Handbuch) the silicon which is always found in aluminium is in part combined with it, and this combined silicon changes by treatment with hydrochloric acid into either silica, which remains, or into silicon hydride, SiH_4, which escapes; while another part of it is combined with the aluminium just as graphite is with iron; and this part remains on treatment with acid as a black mass not oxidized by ignition in the air. Two analyses of aluminium reduced from cryolite by sodium in a porcelain crucible gave—

	1.	2.
Silicon obtained as silica	9.55	1.85
Free silicon	0.17	0.12
Silicon escaping in SiH_4	0.74	0.58

ALLIANCE ALUMINIUM COMPANY, LIMITED, LONDON, ENGLAND.

Founded in 1888. Capital, £500,000. Aluminium up to 99.5 per cent. of purity and aluminium alloys. Works at Wallsend-on-Tyne.

This company manufactures sodium and aluminium by the Netto patented processes. Metallic sodium is produced by percolating caustic soda through a column of hot charcoal in large cast-iron pots. The vapors of sodium rise to the surface and are condensed in suitable apparatus, while the residue, consisting chiefly of carbonate of soda, is withdrawn through a tapping hole in the lower part of the pot. Fresh supplies of charcoal and caustic soda are then introduced, so that the production goes on continuously. Each pot produces 80 to 100 pounds of sodium per day. The residue could easily be reconverted into caustic soda, but the company has found it more advantageous to sell it. The aluminium is made by a modification

of the Deville process, which is the decomposition of aluminium-sodium chloride by sodium with cryolite or fluor spar as a flux.

The Alliance Company uses the mineral cryolite (an aluminium-sodium fluoride), which they obtain under a special arrangement with the owners of the only known mine in the world, in Greenland. It has been known since 1855 that aluminium could be obtained from this mineral by reduction with sodium, in which year it was announced by H. Rose. The product, however, was low in quantity in proportion to the amount of sodium used. The Alliance Company melt the cryolite in reverberatory furnaces, probably with sodium chloride, and it is then suddenly brought into contact with the sodium, whereupon the reaction is completed in a few minutes and the aluminium is separated. Netto used a vessel swung on trunnions, in which the sodium was placed and covered by a perforated aluminium plate. The melted cryolite was poured upon the plate, which caused the sodium to rise more slowly through it and effect the reduction. The contents were then poured into settling vessels. This, or a similar method, is probably used by this company. The resulting slag, consisting of sodium-fluoride and chloride, is reconverted into aluminium-sodium fluoride by decomposition with aluminium sulphate. The sodium sulphate is removed by washing with water.

The exhibits of this company consisted of two hollow blocks of aluminium, one placed upon the other, the lower one about 3 by 4 feet and 2 feet high, the upper smaller. The columns and balustrades were made of aluminium sheet, rolled to shape. Metallic sodium in globes was also shown. This metal was offered in Paris at 20*s* per pound in the summer of 1889.

This company received a gold medal.

BERNARD FRÈRES, PARIS.

An exhibit of aluminium, pure and in its alloys; ingots, plate, tubes, castings, etc.

They use the electrolytic process of Adolph Minet. This process consists in the electrolysis of a melted bath, when aluminium fluoride, in the state of a single or a double salt, is used, not as a flux but as the main electrolyte, being subjected to the influence of the current. The decomposition takes place in a crucible of refractory earth, or of plumbago, or of metal, and when an alloy is required, the crucible may serve as the cathode or as the anode. The crucible is inclosed in a brick covering to avoid filtration. In making pure aluminium a derived current is used on the crucible, and an inner crucible of fused alumina or fluoride of calcium or carbon to receive the metal. The bath may consist of aluminium fluoride 40, sodium chloride, 60; or cryolite 20 to 50, sodium chloride 80 to 50; or aluminium fluoride 35, sodium fluoride 10, sodium chloride 55.

Electrodes.—For aluminium: carbon, or anode carbon cathode, copper or cast-iron.

For aluminium bronze: anode, red copper or carbon; cathode, copper or carbon.

For ferro-aluminium: anode, iron or carbon; cathode, iron or carbon.

In making pure metal the charge is melted in the iron crucible, protected by the brick covering, and the current passed through it. The cathode of carbon is placed in an inner small crucible, as mentioned before, and the outer crucible is protected from the corroding action of the bath by passing a derived current which is diminished by the interposition of a resistance coil. An alloy of aluminium and of the metal of the tank is formed which protects the latter from the action of the bath.

In making an alloy, the tank or crucible is made of the metal which forms a component part of such alloy. The anodes are of carbon and the crucible is the cathode. As fast as the aluminium is produced there is formed on the inner sides of the crucible a layer of aluminium alloy. When this alloy is sufficiently rich in aluminium, the metal formed anew runs to the bottom of the crucible; a tap-hole at the bottom is provided for the withdrawal of the alloy. For each kilogramme of aluminium, 3 kilogrammes of aluminium fluoride would be added, but half of the salt is regenerated by adding alumina. To produce 100 kilogrammes of aluminium there would be required:

	Kilogrammes.
Aluminium fluoride	150
Alumina	200
Sodium chloride	100

To produce this quantity, it is stated that 200 horse-power, for 20 hours, will be required, and twenty-five crucibles for pure aluminium or eighteen for alloys. This is equal to 25 grammes per horse-power per hour.

This firm received a gold medal.

COWLES ELECTRIC SMELTING AND ALUMINIUM COMPANY, LOCKPORT, NEW YORK.

This company exhibited specimens of corundum and of aluminium alloys, silicon bronze, aluminium bronze, etc. It uses the Cowles patent, date of 1885. The works at Lockport were first operated in 1886, utilizing a water-power, of 1,000 H. P. producing aluminium and silicon alloys. Bauxite from France is used in the production of ferro-aluminium and corundum from Georgia for aluminium bronze and brass. The annual product is valued at $150,000.

The works at Stoke-on-Trent, England, commenced operations in 1888, employs steam power equal to 600 horse-power, and gives a product of £20,000 annually.

This company received a gold medal.

STATEMENT BY THE COMPANY.

The basis of the Cowles process is the production of an incandescent heat never before obtained in any furnace, its intensity being sufficient to reduce the most refractory ores—the intensity and application of such heat being under perfect control and of practical use. The principal use to which the process hereinafter described has been confined so far is to the direct reduction of aluminium and silicon ores, but the experience gained makes it highly probable that it may be applied at no distant date to the reduction of all refractory ores and even the baser metals.

The primary agent is electricity, or the direct conversion of energy into heat, in a defined zone of moderate dimensions. In practice we produce aluminium from bauxite or any clay which contains a moderate percentage of alumina. To produce this heat we can employ either the direct or alternating type of dynamo, thus proving that the reduction is not dependent on electrolysis. Assuming that suitable dynamo and leads are provided, the furnace shown is constructed as follows: Consisting of an oblong receptacle, the internal dimensions being 5 feet long by 3 feet 3 inches deep, and 20 inches wide.

The furnace is lined only with one course of fire brick; into the ends are built tubes, as shown, placed at the incline toward the bottom of the furnace, the outer or farther end being carefully closed round the electrodes to exclude the air. The top of the furnace is covered by a cast-iron plate also luted to fit airtight; the top is provided with a suitable hole to permit of the escape of the gases formed by the intense heat, a suitable uptake being provided to carry them off, such uptake having a trap for the collection of any solids carried off containing any useful waste products, which are periodically collected and returned to the furnace. The electrodes within the furnace consist of carbon rods or plates of ample capacity to carry the current to the materials operated on without being themselves overheated. The charge to be acted on is placed between the electrodes, as shown, and is mixed with sufficient broken carbon, which, being a conductor of very high resistance, becomes intensely incandescent and reduces the surrounding ores. To prevent injury to the furnaces each charge is surrounded by a cheap and readily provided lining specially prepared for the purpose. The drawing shows the arrangement of leads, etc. The form of the furnace shown is of the older type in common use, which is, however, being materially modified so as to concentrate the zone of heat and equalize the resistance by which the waste of energy will be reduced. Several runs have been made by which a pound of aluminium has been produced with an expenditure of 17 estimated horse-power per hour, from this will be seen the low cost of production. Up to the present time, we have produced a rich alloy only in the furnace, in cop-

per alloys up to 42 per cent., in ferro, say, to 27 per cent. Thus, in charging the furnace, we add the desired quantity of copper or iron to the bauxite, corundum, or other clay used, the rich alloy produced being graded and standardized by the addition of copper or iron.

The following is extracted from a pamphlet issued by the Cowles Company:

ALUMINIUM BRONZE.

Composed of aluminium and copper; has great tensile strength, high resistance to compression, low specific gravity, and greater resistance to oxidation, corrosion, or sulphurizing action than any alloy known. Forges hot or cold, and can be remelted several times without detriment to its qualities. Its elastic limit is higher than that of mild steel. It can be graded either as to extreme hardness or great ductility, as may be required.

Average strength, etc., in castings.

Grade.	Tensile strength per square inch.	Elongation.
	Tons.	*Per cent.*
A (11 per cent.) (special hard)	45 to 50	Nil to 5
A 1. (10 per cent.)	40 to 45	4 to 8
A 2. (10 per cent.)	34 to 38	8 to 17
A 3. (10 per cent.)	28 to 32	18 to 25
B (7½ per cent.)	25 to 28	25 to 30
C 1. (5½ per cent.)	21 to 25	30 to 35
C 2. (5 per cent.)	18 to 21	35 to 40
C 3. (5 per cent.)	15 to 18	40 to 50
D (2½ per cent.)	12 to 15	45 to 60
E (1¼ per cent.)	9 to 12	20 to 35

The A special hard, A 1, and A 2 grades retain their strength through a great range of temperature. The B and C grades roll and forge hot, and draw cold. The color of these latter grades is similar to 18 carat gold, and retain take and a brilliant polish.

Supplied in ingots, castings, sheets, rods, and wire.

(N. B.—The above-named alloys can be used to advantage by founders for intermixture with their present gun metals, brasses, and bronzes.)

ALUMINIUM BRASS.

This remarkable and cheap alloy is made by combining aluminium copper (aluminium bronze) with spelter in such different proportions as to meet the requirements of the special uses for which it may be employed. It is a close grained, homogeneous, and tough metal, has great tensile strength (up to 42 tons in castings), combined with a remarkably high transverse elastic limit and wonderful elastic resistance.

Average strength, etc., in castings.

Grade.	Tensile strength per square inch.	Elongation.
	Tons.	*Per cent.*
No. 1	23 to 27	10 to 14
No. 2	36 to 38	8 to 11

Transverse test.—In a bar of aluminium brass No. 2, 1 inch square and 12 inches between supports, the breaking load is 72 cwts., deflection with 44 cwts. load 0.04 of an inch, and the permanent set 0.01.

Aluminium brass forges hot, and, owing to its special casting and noncorrodible qualities, low specific gravity, strength, toughness, and rigidity, is especially suitable for such purposes as ships' propellors, stern and rudder frames, pump plungers and rods, valves, wheels, pinions, etc.; also for hydraulic and engineering work generally where castings are required with a strength equal to or greater than steel.

Supplied in ingots, castings, sheets, rods, hexagons, etc.

FERRO-ALUMINIUM.

This product may be alloyed with molten steel or iron with absolute precision, it forming a perfect alloy with the entire body of the metal. It renders the molten metal very fluid and insures freedom from blow holes, increased tensile strength, and high elastic limit. With castings of steel, cast-iron, and wrought iron, and in puddled bar iron, etc., its benefit is very marked.

Particulars as to results obtained, and as to its use, furnished on application.

The qualities of the ferro-aluminium, as produced by the Cowles Electric furnace, are:

(1) It may be alloyed with molten steel or iron in any proportions and with absolute precision.

(2) It forms a perfect alloy with the whole body of the metal.

(3) It does not burn out or escape from the molten steel or iron, but remains and exerts its valuable influence even after several remelts.

(4) It can be added in the converter after the blow; in the crucible when it is charged, or by placing the heated cubes at the bottom and pouring the molten steel on top from a second; in the Siemens furnace or in the ladle.

In the using of the alloy it should be bróken into cubes of, say 1 to 2 inches, and these heated to nearly or quite white heat and added to the molten iron or steel in the crucible or ladle at the bottom previous to pouring.

SILICON BRONZE.

Invaluable as a flux in all copper castings, and for wire and castings generally.

Supplied in ingots, castings, and wire.

HERCULES METAL.

The Cowles hercules metal is a cheaper form of aluminium brass, casts splendidly, and, whilst very hard and strong, works well under the tool; is malleable hot, and suitable for all castings where a strong bronze or brass is required. Tensile strength, 30 to 40 tons per square inch; elongation, 10 to 30 per cent., according to grade.

"COWLES" SPECIAL BEARING METALS.

Grade No. 1.—Hardest composition. This alloy is very noncorrodible, designed particularly for bearings for hard steel shafts, running at high velocities, under heavy pressure.

Grade No. 2.—Hard composition—for all uses, such as crank pin-bearings, slide valves, eccentric straps, foot slips, lathe, and mill bearings, etc.

Grade No. 3.—Medium composition—for railway bearings, freight, passenger, and tram cars, and heavy bearings generally.

Grade No. 4.—Soft composition—for all light-bearing uses.

The base of all these alloys for bearings being aluminium bronze instructions will be furnished founders for mixing with tin, zinc, and lead, to produce the grade required.

Several important firms have used the above-bearing metals and obtained excellent results. A leading London tramway company tested bearings made from grade No. 2 against ordinary gun-metal bearings, and after a year's wear the former were practically as good as on the day they were put on, whilst the latter showed a wear of fully 33 per cent.

MANIPULATION OF ALUMINIUM BRONZE.

The following general instructions for the manipulation and working of aluminium bronze are here noted for the general guidance of our customers:

Casting.—The melting point of aluminium bronze varies slightly with the amount of aluminium contained, the higher grades melting at a somewhat lower temperature than the lower grades. The A grade melts at about 1,700° F., a little higher than ordinary bronze or brass.

Aluminium bronze shrinks about twice as much as brass, and hence due allowance has to be made for this in the mold and pattern. As the metal solidifies rapidly it is necessary to pour it quickly and to make the gates amply large, so that there will be no "freezing" in the "gates" before the casting is properly fed. To obviate the shrinkage as much as possible the metal is allowed to enter the mold at a temperature no higher than will admit of it running freely. Where there is a heavy mass of metal in the shape of an envelope surrounding a core the contraction upon solidification will cause the metal to split unless the core is made to yield equally with the contraction. Baked sand molds are preferable to green sand, except for small castings.

One of the chief difficulties met with in the casting of aluminium bronze is to avoid the oxidation in transferring the metal from the crucible or ladle to the mold. If any of the film of oxide which floats on the surface of the metal should get into the casting during the pouring it will appear there like so much dirt, and is apt to cause trouble. The ordinary skim-gate will prevent this in the case of small castings, but with large masses the metal is first poured into a receiver, which is connected with, and is part of, the pouring "gate," but is prevented from entering the mold by means of a plug which closes up the mouth of the "gate." To illustrate this more clearly imagine the pouring "gate," shaped like a funnel, into which the metal is first poured. It is prevented from running into the mold by the plug already mentioned. As soon as the dirt has risen to the top the plug is withdrawn, and consequently nothing but the clear metal of the bottom enters the mold. For castings over 50 pounds the metal is poured from a large ladle through a hole in the bottom. Ample facilities should be made for the escape of gases.

Both aluminium and copper volatilize only at extremely high temperatures, and consequently aluminium bronze can be frequently remelted without any appreciable change in the strength or quality or the metal whatever. This fact has an important bearing upon the economy of its use.

Like brass, all billets and slabs for rolling into sheets, rods, bars, and wire, are cast in iron molds, but by a method which differs from the usual way of casting brass slabs very materially, and with results far superior to the latter. "Cold shut" edges, rough surfaces, and "blowy" or "dirty" metal, so common to brass slabs, are unknown to slabs and billets of aluminium bronze. Those who are familiar with the rolling, drawing, and spinning of metal will appreciate at once the immense advantages of having perfect stock to begin with. In finely finished sheets the brilliancy and luster to which the bronze is susceptible is not dimmed by speck or blemish of any kind.

Working qualities.—Aluminium bronze is an extremely dense or close-grained metal. The stronger a metal is, or, in other words, the greater the force of cohesion between the particles, the greater the force necessary to overcome that cohesion. For this reason aluminium bronze works harder under the tool than a weaker

metal, which should be expected. But experience soon teaches what is the proper temper for the tool and the right way to sharpen it, and then any difficulty that may appear to those unaccustomed to handling the metal will soon vanish. The fracture of special and A grades exhibit a crystalline structure; the lower grades are extremely fibrous. The former works similar to machinery steel; the latter more like wrought iron.

All the grades, except the special, can be rolled, swedged, spun, or drawn cold, but because of their greater ductility the lower grades can be drawn cold much easier and to a much greater extent before annealing than the higher grades. Aluminium bronze is the only bronze in the arts that is not "hot short," and can be worked at a bright red heat as easily as wrought iron. The advantages accruing from this fact alone are almost too numerous to mention. For gas burners of any kind, tuyéres for blast furnaces, or any place where brass and other bronzes will break short when heated to a redness (which, moreover, causes oxidization, and volatilization of the zinc in the former), the value of this bronze becomes apparent. Under the blacksmith's hammer it can be drawn out to the fineness of a cambric needle. The rolling of sheets, rods, bars, and wire is done at a bright red heat, only the finishing being done cold. The only way to harden or stiffen the metal is to work it, but by subjecting it to the proper temperature in the annealing furnace it soon softens again.

Rolling or working the metal in any way makes it stronger and tougher. For instance, the test of a rolled rod of the B grade, tested, showed a tensile strength of 83,000 pounds to the square inch with 39 per cent. elongation before breaking. In the casting this metal has but 60,000 to 65,000 pounds tensile strength with about 20 per cent. elongation. All the grades are perfectly malleable at a red heat, while the special and A grades break less and elongate more than pure copper at this heat. The metal should be rolled at as high a heat as possible below fusion. In rolling, swedging, or spinning cold, it should be annealed very often, else it is liable to break very quickly after it ceases to elongate. It can be made softer by annealing at a bright heat, cooling in still air to redness, and then tempered by plunging into cold water, than by simply annealing.

Small castings of aluminium bronze.—We find it an advantage in making small castings to have the top of the feeder-gate considerably higher than the body of the casting. By the high head or pressure of metal every portion of the mold is filled accurately, and such large sprews for feeding are not necessary.

MANIPULATION OF ALUMINIUM BRASS.

Aluminium bronze, when added to ordinary brass in almost any proportion, greatly improves the brass in strength, toughness, and resistance to corrosion. The more aluminium bronze is added to brass the harder and stronger the brass becomes. Tests have been made where castings of aluminium brass have gone as high as 96,000 pounds in tensile strength to the square inch.

Cost.—It will be observed that the first cost of aluminium brass is much cheaper than aluminium bronze in castings of the same strength by reason of it containing less aluminium than the bronze, besides a considerable quantity of zinc, which is a very cheap metal.

Casting.—Practically the same rules to be observed in casting aluminium bronze (see article entitled Aluminium Bronze) are applicable to the casting of aluminium brass.

Working qualities.—Aluminium brass works under the tool similar to aluminium bronze—those brasses that are high in aluminium working similar to the high grade bronze, those that are low in aluminium like low grade bronze. The working qualities are also governed largely by the quantity of zinc contained in brass—the higher the percentage of zinc the harder the metal and the shorter the chip which flies from the tool.

Messrs. Lehmann exhibited at the Paris Exposition an alloy of aluminium and manganese which had been forged, but of which I was unable to learn the particulars.—W. H. C.

SOCIÉTÉ ANONYME POUR L'INDUSTRIE DE-L'ALUMINIUM, NEUHAUSEN, FALLS OF THE RHINE, SWITZERLAND.

Capital, 10,000,000 francs. Exhibits aluminium, ferro-aluminium, aluminium bronze, forged and rolled and hammered articles of the latter alloy.

This company use the electrolytic process invented by P. L. C. Heroult, of Paris, for the production of aluminium and its alloys. The production of aluminium is not probable by this process, the alloys only being obtained.

The apparatus consists of a wrought-iron box, lined with carbon slabs and having cover of the same. A tap-hole at the bottom allows the withdrawal of the metal. A hole in this cover allows the introduction of the large carbon anode, which is connected with the dynamos by copper cables. The carbon bottom of the vessel is also connected. Copper is introduced into the vessel and the carbon anode is approached to it. When the copper is melted by the current the aluminium ore is introduced, which is melted and floats above the copper. The alumina is decomposed, the aluminium alloying with the copper and the oxygen combines with the carbon anode. The anode is kept as close to the melted copper as possible without dipping in it.

It is claimed that 35 to 40 grammes of aluminium per horse-power per hour are obtained by this process, which is equal to 1 pound for 13 to 11 horse-power. Practice indicated the production of 22⅔ grammes per horse-power per hour alloyed with copper, forming a bronze containing 22 per cent. aluminium. The power is obtained from a turbine of 300 horse-power.

This company claims to produce aluminium by the Kiliani process, which has not been published. In a circular is given, motive force 4,000 horse-power, workmen 200, annual production aluminium pure 90,000 kilogrammes, aluminium bronze 1,500,000 kilogrammes, ferro-aluminium 1,000,000 kilogrammes.

Aluminium guarantied 99 per cent., price 25 francs per kilogrammes.

This company received a gold medal.

SOCIÉTÉ ANONYME ELECTRO-METALLURGIQUE FRANÇAISE, PARIS, FRANCE.

Works at Froges (Isere), France. Capital, 650,000 francs. Exhibits alloys of aluminium with copper, iron, and tin severally, in forms of ingots, bars, and sheets. Also silicon copper 12 per cent., and silicon iron.

This company owns the Heroult patents for France.

An American company operates the process at Boonton, New Jersey.

A. R. Pechiney et Cie., Salindres (Gard), France, exhibited aluminium. A communication received from this firm states that they obtain the metals of the alkalies and aluminium by the old process (Deville). From 1874 to 1882 this firm were the only producers of aluminium in the world. Their annual product was about 5,000 pounds.

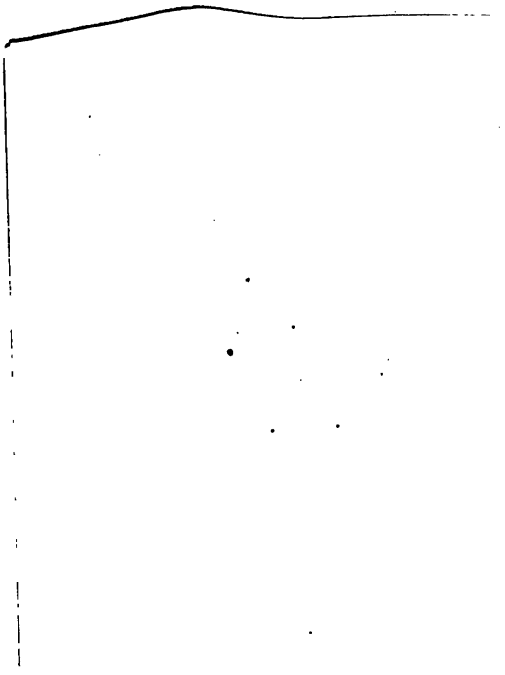
PITTSBURG REDUCTION COMPANY, PITTSBURG, PENNSYLVANIA.

This company did not exhibit at Paris, but as it is the most recently established company successfully at work, it is proper to mention it here.

This company, established in 1888, uses the patents of Charles M. Hall, date of 1889. Mr. Richards describes this establishment in his work on aluminium.

Two reducing pots of cast-iron lined with carbon are used, the lining forming the negative electrode, and six to ten carbon cylinders 3 inches in diameter, the positive electrode. The pots are 24 inches long, 16 inches wide, and 20 inches deep, holding 300 pounds of the bath. This bath, as now used, is composed of aluminium fluoride, cryolite and fluor spar melted together in theproportions represented by the formula, $Al_2F_6 6NaF + Al_2F_6CaF_2$. When the bath becomes clogged it is cleared by adding 3 or 4 per cent. calcium chloride. The bath is kept melted by the electric current, nearly at the melting point of brass. During the operation, alumina, obtained from aluminium hydrate, is fed in, and this only is decomposed, the fluoride solvent wasting only slightly. In making alloys, as bronze, both electrodes are of copper. The bronze formed at the cathode drips down melted to the bottom of the vessel. About a pound of aluminium per hour is produced in each pot, and the operations are kept up without stopping for several weeks at a time. A 50 horse-power engine driving two dynamos effects the reduction, this is equal to about 20 grammes per horse-power per hour. This is about 300 pounds per week. It is said a plant is to be erected of a capacity of 2,500 pounds per week, and one of the same size in England.

This company offer their aluminium at $2 per pound. Mr. Richards estimates the cost of this metal at $1 per pound, with the large plant at not over 50 cents.



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